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Twenty Years' Spraying for Potato Diseases

Potato Diseases and the Weather

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BULLETIN 151: PLANT DISEASES

Twenty Years' Spraying for Potato Diseases
Potato Diseases and the Weather

By B. F. Lutman

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STUDIES IN PLANT DISEASES

The year 1910, like the three preceding it, was inclined to be rather dry during the summer months and there were no periods of excessive and continued rainfall. To this fact is largely due the absence of any marked outbreak of fungus plant diseases. Those that occurred are the ones that, like the poor, are always with us, every season. The year 1909 was a fairly average one as regards rainfall and temperature, so the perennial plants, such as the trees and shrubs, started into 1910 in fairly good condition. It has been repeatedly observed at this Station that, following a very dry summer, numerous reports are made the next season of the partial dying of trees, a result due to the injury to their root systems wrought by the drought.

In 1910, therefore, these nearly average conditions tended to prevent any serious physiological maladies. Only one was observed or reported; but this was quite serious. The leaves on many of the oaks suffered quite severely during August, and by the first of September a third of them were dead. The scorched appearance seemed due to lack of water brought about by excessive transpiration and an enfeebled root system. No fungi were found. A similar condition was frequently reported during the previous season among the maple trees, many of which died without visible reason, save lack of water. The oaks, however, did not suffer seriously at that time.

The *pear and apple scab* is still the most persistent and frequent of orchard fungus enemies, but the better growers are rapidly learning that clean and perfect fruit brings much better financial returns than does that which is scabby and misshapen, and that such can be produced if proper care is taken. This means that the trees must be sprayed at least three times, either with the weak lime-sulphur mixture or with weak bordeaux mixture. These fungicides should be applied just before the blossoms open, just after the petals fall, and at least once afterward (see bulletin 113, pages 96, 103).

Pear blight does not seem to be as common as formerly, due probably to the fact that growers have found out that it may be exterminated by pruning out the dead limbs, either in the fall or the early spring before the sap begins to flow. This pruning must extend several inches back of the point where the limb is dead, however, and the tools used should be disinfected after each operation, by dipping them in a solution of one part of commercial formalin to ten parts of water.

In spite of the ease with which *black knot* may be prevented and its destructiveness to plum and cherry trees when once it attains a good start, it is still found in many Vermont orchards. The same procedure as is used against the pear blight will free these trees of this disease; and it is an easier task, since the constant disinfection of tools is not essential.

Apple rust has never become an important factor in Vermont orcharding, yet it was reported several times during the summer, in one case entire trees in an orchard being ruined by it. The removal of the red cedar, the secondary host that harbors the fungus, is not practicable in most parts of the State; and spraying is not entirely effectual.

Oat smut is a disease from which Vermont fields have been comparatively free, at least in comparison with western conditions where the loss in some cases runs as high as 15 percent of the entire crop. Yet several fields were noted in this State where the number of infected heads must have amounted to 5 or 10 percent of the entire number. These oats, grown from Vermont seed, show that smut is again becoming an important disease here. The ease with which it may be prevented by treating the seed oats over night with a weak formalin solution (1 pint of formalin to 30 gallons of water) should be known to every farmer who raises oats. It can be done at any time during the winter and is a certain preventive (see bulletin 113, page 100).

Club root of cabbage is spreading throughout the State and before many years it will be found in nearly every garden where

this crop is raised. The disease is spread largely through the sale of cabbage plants sent to market in greenhouse flats, but infected soil may be carried on the shoes or in the hoofs of horses. When the soil has once become inoculated with the fungus, it is years before cabbage, cauliflower, turnips or any member of that group of plants can be successfully grown again. If plants for setting out are bought instead of being raised, the buyer should be sure that they have not been grown in infected soil.

Pea and *chrysanthemum* plants affected by *wilt* were sent to the Station several times from different localities. The cause of the trouble seemed to be the growth of one of the Fusariums.[1]

Potato diseases of any sort were rare around Burlington, about the only abundant one being black-leg. This occurred on one end of the field grown on the college farm and was reported to us as present in fields in other parts of the State. Neither early nor late blight were found in this vicinity. Tip-burn appeared on the unsprayed plants during late August and early September, but was not markedly destructive. From other parts of the State have come reports and specimens showing severe attacks of late blight. From along the Connecticut river, where the dense fogs favored its early appearance, blighted leaves were sent early in July. Bad cases of late blight associated with the resulting tuber rot were reported from several towns in the more mountainous regions. A rather interesting fact was brought out in connection with some of these tubers sent for diagnosis. The tubers were rotting badly in storage and betrayed all the appearances of typical Phytophthora infection, such for example as dark sunken areas; yet continued efforts to cause the Phytophthora to appear, by the customary method of splitting the tuber open with a sterile knife and afterward keeping it in a moist chamber, were without results, save in a very few cases. No abundant mycelial development appeared along the inner edge of the brown sunken spots and the scanty fungus growth

[1] In this connection see Bul. 157 on "The damping off of coniferous seedlings," caused by a similar fungus.

which did show apparently consisted solely of saprophytic species. The reasons for this situation were not clear, but it may have been in some way a result of the storage of the potatoes after digging, or of some peculiar weather conditions occurring during September and October.

POTATO SPRAYING

The 1910 trials were made with a view of continuing the studies on the effects of bordeaux mixture on the potato plants themselves rather than of its effect as a deterrent against disease. The results of 19 years of spraying have shown that bordeaux mixture does two things:

1. It very efficiently protects the plants from the attacks of the early and of the late blight.

2. It seems to serve in some way as a stimulus to the plant, so that it remains green from one to two weeks longer than do the unsprayed ones and, also, yields more and larger tubers.

The season of 1910 was an admirable one in which to study the latter phase of the bordeaux problem, for no blights appeared as disturbing factors. Hence any beneficial results wrought by the use of the bordeaux were necessarily due solely to its effect on the potato plant itself and not to the fungal attacks which it may have prevented.

An attempt was made in the 1909 trials[1] to ascertain the particular constituent of bordeaux mixture that produced the stimulus. Plots were sprayed as follows:

(1) With the usual 5-5-50 bordeaux mixture (i. e. 5 pounds copper sulphate, 5 pounds lime, 50 gallons water).
(2) With 4 pounds iron sulphate, 2 pounds copper sulphate, 6 pounds lime in 50 gallons of water.
(3) With 5 pounds iron sulphate, 5 pounds lime in 50 gallons water.
(4) Plants unsprayed, but dusted with paris green and lime.

Iron sulphate occurs as an impurity in commercial copper sulphate. Certain German investigators having claimed that the beneficial effect of bordeaux mixture is due to its small content of iron sulphate, plots 2 and 3 were treated therewith. The

[1]Vt. Sta. Bul. 153 (1910).

yield of potatoes from those plants sprayed with either of the mixtures containing copper was greater than that harvested from the plots treated either with lime or with iron sulphate. The increased vigor of the plants as shown by the larger yield seemed due to the effect of the copper on the leaves.

Two physiological effects of the copper on the plants were noted:

(1) The bordeauxed leaves were thicker and of a darker green color than those which were left unsprayed, apparently indicating that the plant was healthier and, on account of its greater amount of chlorophyll, producing more starch.

(2) The plants thus treated suffered less from tip-burn than did those not bordeauxed and lived from ten days to two weeks longer, apparently indicating that transpiration is retarded. The question now arises whether the increased quantity of tuber yield is due to an actual stimulus of the plants throughout the growing season, or whether it is due to the prolongation of life. There can be no question that an increase in yield results when Vermont potatoes are sprayed with bordeaux. Yet many of the German stations now seem to hold that in northern European climates the bordeaux mixture may so injure the crop as to depress the yield.

The question then is: Does the plant that has been sprayed produce from day to day more starch than does the unsprayed one because of such spraying, or does it produce more starch because it lives longer? The trials of 1910 were conducted primarily with the intention of contributing to the answer of this question. A sufficient number of plots were sprayed and an equal number left unsprayed, so that diggings might be made at intervals throughout the summer and yields compared. If the copper is a benefit, if it increases the ability of the plant to fix carbon dioxid and to form starch, that stimulus should show even in August and September in the increased yield of the tubers from the plants so treated. On the other hand, if the bordeaux has no such effect, or if, perhaps, it induces a

slight injury to the plant, these early harvests in August and September should show no larger, indeed possibly smaller, yields on the bordeauxed plots than on those left untreated.

To guard against the possibility that the stored carbohydrate material had not yet been transferred to the tubers, but had in part remained in the stem and leaves, the tops were weighed in the earlier harvests as well as the tubers. Naturally it was impossible to take this precaution in the final harvest at the close of the season, since the tops were all dead; but, doubtless, the necessity thereof was less imperative.

The combination of iron and of copper sulphates proved nearly as effective in 1909 in keeping the vines green as did the straight bordeaux. It would seem that so far as stimulating the plant is concerned, the iron-copper sulphate mixture is practically as serviceable as is bordeaux, since the yields from both sets were practically identical. The fungicidal value of this mixture has not been determined, hence plots were sprayed therewith as a subsidiary experiment, in case the season should be a wet one and blight so prevalent as to render valueless the principal test.

In order to produce these effects noted on the sprayed plants the copper must be absorbed by the leaves. If the stimulus is a local one, limited to the particular leaves touched by the spray, the effect would be much less than if the copper after being absorbed was distributed over the whole plant, thus making the stimulus a general one. With this question in mind the plants on one of the plots were sprayed on their lower leaves only.

METHODS

Green Mountain potatoes were used as seed, and were sprayed July 11, July 27, Aug. 15, Aug. 23, and Aug. 30, as follows:

(1) Three plots were left unsprayed to serve as checks.

(2) Three plots were sprayed with 5-5-50 bordeaux mixture, a half pound of paris green being added as an insecticide. Application was made at the rate of about 250 gallons per acre.

(3) One plot was sprayed with a mixture composed of four pounds of iron sulphate, two pounds copper sulphate and fifty gallons of water, to which one-half pound of paris green had been added. Application was made at the same rate as with bordeaux.

(4) Only the lower half of the plants on one plot were sprayed with the 5-5-50 bordeaux mixture.

Additional applications of paris green and lime were made several times during the summer to kill the potato beetles which were fairly abundant.

No early or late blight developed during the season and no tuber rot occurred. Some black leg was observed at one end of the plots, but as this extended in a narrow strip of about uniform width across all of the experimental area and was not very serious in its effects on the plants, no account is made of it.

RESULTS

Harvests were made at three different times during the fall: September 2, September 16, and October 20.

The first harvest (September 2) consisted of the tubers from a plot sprayed with bordeaux mixture and those from a control plot.

	Marketable tubers per acre	Small tubers per acre	Total per acre
Sprayed with bordeaux mixture	167.9 bushels	26.9 bushels	194.8 bushels
Control	130.5 bushels	39.5 bushels	170.0 bushels

At this time the unsprayed plants had already suffered considerably more from tip-burn than had the sprayed ones. This was not so evident in the weight of the tops, however, as the average weight of the unsprayed tops was .7533 pounds, while that of the sprayed tops was .8085 pounds.

The second harvest (September 16) of two similar plots gave the following results:

	Marketable tubers per acre	Small tubers per acre	Total per acre
Sprayed with bordeaux mixture	275.8 bushels	24.0 bushels	299.8 bushels
Control	177.6 bushels	33.2 bushels	210.8 bushels

As compared with the results attained 14 days earlier the sprayed plants were much greener and more free from tip-burn than were the unsprayed ones. The average weight of the green tops of the control plants was at this time only .341 pounds, and the dry weight, .0552 pounds, while that of the sprayed plants averaged .666 pounds per plant, and the dry weight, .164 pounds.

The final harvest was made October 20. At this time all the plants, both sprayed and unsprayed, were dead and no attempt was made to weigh the tops.

	Marketable tubers per acre	Small tubers per acre	Total per acre
Sprayed with bordeaux mixture	220.7 bushels	19.6 bushels	240.3 bushels
Sprayed with bordeaux mixture plus iron sulphate	226.5 bushels	26.0 bushels	252.5 bushels
Sprayed with bordeaux mixture on half of the plant	208.7 bushels	21.4 bushels	230.1 bushels
Control	177.5 bushels	24.6 bushels	202.1 bushels

The results attained in the two September harvests would indicate that even early in the season, bordeauxed plants store more starch in their tubers than do those not thus treated. While the plants themselves both from the bordeauxed and the control plots were of approximately the same size, as indicated by the average individual weight, the slight difference of .0533 pounds being due to the small excess of tip-burn on the unsprayed plants, the weight of the tubers at this time was 24.8 bushels per acre in favor of the potatoes to which the bordeaux had been applied. This would seem to indicate that during the months

of July and August while the tubers were growing that the unsprayed plants were not able to fix as much carbon dioxid and transform it into starch as were those that had not been so treated.

The conclusions that may be drawn from the harvest of September 16 at this time are not as decisive as those of September 2, as the tip-burn had made rapid progress on the unsprayed plants during the intervening two weeks and the individual plants on the control plot were only half as heavy as those on the sprayed plots. At the same time the sprayed plants yielded 89 more bushels of tubers per acre than did those on the control.

The harvest of October 20, made when all the vines were dead, confirms again the results of the past 19 years' spraying of potatoes at the Vermont station. Bordeaux mixture, even in years like 1910 when no blight occurs, increases the yield of the plants to which it is applied. This increased yield is always sufficient to pay for the cost of spraying operations. Spraying is to be regarded as an insurance that pays for itself. If the blights are prevalent, the potatoes, if thoroughly sprayed, are insured against loss therefrom; if the season is a dry one and no disease occurs, still the crop will be enough larger to pay for all the cost of spraying. The careful potato sprayer wins either way, no matter what the weather or disease conditions.

From these results it would appear also that the application of the iron sulphate-copper sulphate mixture has practically the same effect on the vines as does the ordinary bordeaux. In fact this year the plots so sprayed yielded more than did the bordeauxed ones. Last year the yield from the bordeauxed plots was 243 bushels per acre, while that from the bordeaux mixture and iron sulphate was 235 bushels per acre. The results of the two years taken together would show that in its effect on the plant, the bordeaux in which part of the copper is replaced by iron has as great a stimulating effect as does the ordinary bordeaux. Whether it is as good a fungicide has not yet been proved.

The increased yields from plots where the bordeaux mixture was applied only to part of each plant indicates that even here there was a sufficient effect produced to manifest itself in a yield of 28 bushels per acre more than that obtained on the plots left entirely untreated. This is about what would be expected if half the leaves were touched by the bordeaux.

TWENTY YEARS' SPRAYING FOR POTATO DISEASES

In view of the fact that 1910 marked the close of twenty seasons of experimental spraying against potato diseases at this Station, as well as the departure of all the men hitherto engaged in this line of work, it has seemed desirable to summarize the results that have been obtained during this period in such a form that they may be available to any who may be interested therein, especially since most of the earlier reports and bulletins detailing these results are now out of print. And this despite the fact that bulletin 72 was issued in 1899 which reviewed the situation to date; and that in the resumé report of 1907 which marked the close of twenty years of station existence, the matter was written up to that date, albeit in extremely condensed form.[1] There seems ample reason now, however, for making one more general publication and of closing the chapter for good and all so far as the type of trial thus far carried out is concerned. Those who have similar potato diseases to combat may find it worth while to become acquainted with the success or failure of the many attempts made against these maladies as achieved here; and it is the purpose of this bulletin to set forth these facts in as convenient form as may be for such ready reference.

Beginning with 1891 the experimental trials were conducted under the general direction of Prof. L. R. Jones, the then station botanist, save that last year's (1910) trials were made by the writer. During this time several assistant botanists contributed to the success of the trials, more particularly C. E. Stevens, the late C. C. Tracy, A. J. Grout, W. A. Orton, the

[1]Vt. Sta. Rpt. 20, pp. 389-402 (1907); also Bul. 136, pp. 195-199 (1907).

late A. W. Edson, W. J. Morse, N. J. Giddings, and the writer. Starting with the protection of the plants against the late blight by means of sprays, other problems, such as the best spray mixture to use, protection against early blight, effect of the spray mixture on insect injury and on the plant itself, have arisen.

The first statement touching late blight of the potato, made in the publications of this Station was issued in 1888,[1] although it had undoubtedly been present and destructive in Vermont fields many years before.

The blight was again prevalent in 1889.[2] Bordeaux mixture had been recently suggested by the United States Department of Agriculture as a fungicide for use against the downy mildew and black rot of the grape. Thinking that it might be of service also against the late blight of the potato, some attempts were made late in the season, after the disease had a good start, to use it on the potato vines. The mixture was made according to the following formula: Copper sulphate 4 pounds, dissolved in 16 gallons of water; lime 4 pounds, dissolved in 16 gallons of water. The solutions were mixed and allowed to stand two days before application. Part of a small field was sprayed once with this mixture and part twice. The latter section remained green much longer than did the former. The results were on the whole so favorable that it was resolved to give the mixture a thorough trial the following season.

Experiments were undertaken in 1890[3] to determine the effect of one and two sprayings and the relative resistance to rot of about 200 varieties of potatoes at that time in cultivation on the station farm. The bordeaux mixture used was formulated as follows: Six pounds copper sulphate dissolved in 8-10 gallons of water; 4 pounds lime slaked and diluted with water to form a thin paste. The lime poured into the copper sulphate solution and the mixture diluted to 22 gallons.

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[1] Vt. Sta. Rpt. 2, p. 121 (1888).

[2] Vt. Sta. Newspaper Bul. 2 (1889); Vt. Sta. Rpt. 3, pp. 117-118 (1889).

[3] Vt. Sta. Bul. 24 (1891); Vt. Sta. Rpt. 4, pp. 131-138 (1890).

The acre yields of marketable tubers obtained were: Sprayed twice, 165¼ bushels; sprayed once, 155 bushels; not sprayed, 86 bushels.

The data as to the resistance of the different varieties to rot were inconclusive.

1891. This year is regarded as the first of the 20 years' series, the two previous years' work being really preliminary in their nature. A comparative test of four fungicidal compounds was made:[1]

(1) Stronger bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 33 gallons water).
(2) Ammoniacal copper carbonate (5 ounces copper carbonate, 3 pints ammonia, 45 gallons water).
(3) Glue mixture (12 ounces sodium carbonate, 10 ounces copper sulphate, 8 ounces liquid glue, 45 gallons water).
(4) Bordeaux mixture, half strength.

White Star potatoes, a late variety, were sprayed on August 20 and September 8. Both the glue mixture and the ammoniacal copper carbonate seriously injured the leaves. Furthermore they were not as efficient as fungicides as were either the stronger or weaker bordeaux mixtures, of which the stronger proved the better.

The acre yields in bushels were: Sprayed with strong bordeaux mixture, 313; unsprayed, 248; gain, 65.

The presence of a very destructive potato disease—later called "early blight"—was noted for the first time by the station botanist. Many fields were devastated from it by mid-August and all were dead by September 1.

1892. The chief problem was a test of twelve promising fungicides,[2] including three strengths of bordeaux mixture. They were as follows:

(1) Copper-soda solution (8 pounds copper sulphate, 12½ pounds sal soda, 50 gallons water).
(2) Verdigris solution (5 pounds verdigris, 50 gallons water, reduced one-half after first application).
(3) Bordeaux mixture and molasses (8 pounds copper sulphate, 8 pounds lime, 8 pounds molasses, 50 gallons water).

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[1] Vt. Sta. Bul. 28 (1891); Vt. Sta. Rpt. 5, pp. 129-132 (1891).
[2] Vt. Sta. Rpt. 6, pp. 57-70 (1892).

(4) Ammoniacal copper carbonate (5 ounces copper carbonate, 3 pints strong ammonia, 45 gallons water).
(5) Copper and ammonium carbonate (1 pound copper carbonate, 2 pounds ammonium carbonate, 50 gallons water).
(6) Glue mixture (10 ounces copper sulphate, 12 ounces sal soda, 8 ounces liquid glue, 25 gallons water).
(7) Modified eau celeste (4 pounds copper sulphate, 5 pounds sal soda, 3 pints ammonia, 45 gallons water).
(8) Copper carbonate in suspension (1 pound copper carbonate precipitated, 25 gallons water).
(9) Copper chlorid (3 ounces copper chlorid, 22 gallons water).
(10) Strong bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 22 gallons water).
(11) Weak bordeaux mixture (5 pounds copper sulphate, 5 pounds lime, 50 gallons water).
(12) Very weak bordeaux mixture (1 pound copper sulphate, 1 pound lime, 30 gallons water).

White Star, a late potato, was used and the mixtures applied July 30, August 13 and August 25.

The late blight was highly destructive, appearing early and causing much tuber rot later, hence an excellent opportunity was afforded of testing the comparative efficiencies of the several fungicides. Strong bordeaux mixture, bordeaux and molasses, weak bordeaux mixture and modified eau celeste were the only sprays whose merit recommended them for practical use. The other eight sprays were beneficial, but did not rank therewith. The acre yields in bushels were: Strong bordeaux mixture, 291 bushels; weak bordeaux mixture, 164 bushels; bordeaux mixture with molasses, 354 bushels; modified eau celeste, 291 bushels; unsprayed, 99 bushels.

The addition of the molasses to the bordeaux increased its fungicidal value, but since it was thought that it might prove a source of danger to bees, its use was not recommended.

A supplemental experiment was made, spraying twice and three times, with the following results per acre:

	Sprayed twice	Sprayed three times
Strong bordeaux mixture	157 bushels	291 bushels
Bordeaux mixture and molasses	265 bushels	354 bushels
Ammonium copper carbonate	86 bushels	105 bushels

The ravages of the potato disease noted the year before were still worse in 1892. Its careful study led to its being named

"early blight," despite the fact that it sometimes occurs late in the season. The fungus *Macrosporium solani*[1] was found generally associated with the spots and was believed to be the cause, although no inoculation experiments were made.[2]

1893. The trials for this year[3] were designed to determine: (1) Whether spraying early potatoes was profitable; (2) the best all-round potato fungicide. Twenty-two fungicides were tested as follows:

(1) Strong bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 22 gallons water).
(2) Strong bordeaux mixture plus soap (Babbitt's) at the rate of 1 pound soap to 8 gallons of mixture.
(3) Weak bordeaux mixture (1 pound copper sulphate, 1 pound lime, 10 gallons water).
(4) Weak bordeaux mixture plus 1 pound soap to 8 gallons mixture.
(5) Weak bordeaux mixture plus 1 pound soap to 16 gallons mixture.
(6) Weak bordeaux mixture plus molasses, 1 pound in 10 gallons mixture.
(7) Very weak bordeaux mixture (1 pound copper sulphate, 1 pound lime, 20 gallons water).
(8) Very weak bordeaux mixture, plus 1 pound soap to 8 gallons mixture.
(9) Very weak bordeaux mixture, plus 1 pound soap to 16 gallons mixture.
(10) Very weak bordeaux mixture, plus 1 pound soap to 32 gallons mixture.
(11) Ammoniacal copper carbonate, (5 ounces copper carbonate, 3 pints ammonia, 45 gallons water).
(12) Ammoniacal copper carbonate, plus 1 pound soap to 16 gallons of the solution.
(13) Copper and ammonium carbonates (1 pound copper carbonate, 2.2 pounds ammonium carbonate, 50 gallons water).
(14) Copper and ammonium carbonates, plus 1 pound soap to 16 gallons of solution.
(15) Modified eau celeste (4 pounds copper sulphate, 5 pounds sal soda, 3 pints strong ammonia, 45 gallons water).
(16) Modified eau celeste, plus 1 pound soap to 16 gallons of the solution.
(17) Modified eau celeste, plus 1 pound soap to 32 gallons of the solution.
(18) Sulpho-steatite, heavy application.
(19) Sulpho-steatite, lighter application.
(20) Copper sulphate (1 ounce in 100 gallons water).
(21) Copper sulphate (8 ounces in 100 gallons water).

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[1] That the fungus should be called *Alternaria solani* was proved later; (Vt. Sta. Rpt. 9, 79-87, 1895).

[2] The causal relation of the fungus to the malady was later determined by inoculation (*loc cit.*).

[3] Vt. Sta. Bul. 40 (1893); Vt. Sta. Rpt. 7, pp. 40-60 (1893).

(22) Copper sulphate solution (No. 20), plus 1 pound soap to 16 gallons.
(23) Copper sulphate (2½ pounds in 100 gallons water), plus 1 pound soap to 8 gallons.

The late blight was not very destructive, but there was much rot of the tubers in the field.

Spraying early varieties.—Early Rose and Polaris were used. The results stated as bushels per acre may be summarized as follows:

Polaris.—Sprayed three times (bordeaux), 254; unsprayed, 170.

Early Rose.—Sprayed 2 times (bordeaux), 246½; unsprayed, 111½.

The stronger bordeaux mixture was found to be the most effective fungicide on the early varieties, but the weaker mixture proved to be nearly as effective.

Spraying late varieties.—White Star was sprayed three times. The gain from spraying the late potatoes was greater than that from spraying earlier ones. Stated as bushels per acre it was: Sprayed 3 times (strong bordeaux), 338; unsprayed, 114.

In all cases the strong bordeaux mixture proved the best fungicide, with the weak mixture a close second. Modified eau celeste was the only other fungicide of practical value and it did not afford as satisfactory results. A few others had slight value.

The leaves sprayed with bordeaux mixtures showed a much smaller number of flea beetle punctures than did those left unsprayed. The sprays were more or less deterrent to the flea beetle. The relative numbers under different treatment are:

Check	2400 holes.
Very weak bordeaux mixture	1794 holes.
Ammoniacal copper carbonate	1587 holes.
Modified eau celeste	1376 holes.
Weak bordeaux mixture	1298 holes.
Strong bordeaux mixture	1194 holes.
Bordeaux mixture and soap	945 holes.

1894. The trials[1] were designed to test the relative values of several fungicides:

(1) Stronger bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 22 gallons water).
(2) Weak bordeaux mixture (5 pounds lime, 5 pounds copper sulphate, 50 gallons water).
(3) Bordeaux mixture in the form of a powder. (A commercial powder sold under the name of "Fungiroid" was tried; also a similar home-made powder, prepared by drying and grinding the bordeaux mixture precipitate).
(4) Old bordeaux mixture (prepared in June and used in July and August).
(5) Bordeaux mixture made by the potassium ferrocyanide test (both strong and weak mixtures were used).
(6) Modified eau celeste (4 pounds copper sulphate, 5 pounds sal soda, 3 pints strong ammonia, 45 gallons of water).
(7) Ammoniacal copper carbonate, Delaware formula: (5 ounces copper carbonate, 3 pints strong ammonia, 45 gallons of water).
(8) Fungicides plus soap. Soap was added to the following mixtures: Strong bordeaux mixture made up according to potassium ferrocyanide test, modified eau celeste, ammoniacal copper carbonate.

The year was an unfavorable one for testing the fungicidal value of these mixtures, as the summer months were the driest in years. No disease appeared and any differences shown in the results are due to protection against insects combined with the physiological effect of the fungicides on the potato plant itself.

White Star, Polaris and Early Rose potatoes were planted. Applications were made on June 30, July 18, and August 30. The comparable results are as follows:

Stronger bordeaux mixture	260 bushels per acre
Weak bordeaux mixture	256 bushels per acre
Bordeaux powder	243 bushels per acre
Old bordeaux mixture	229 bushels per acre
Strong bordeaux mixture, ferrocyanide test	241 bushels per acre
Weak bordeaux mixture, ferrocyanide test	242 bushels per acre
Modified eau celeste	240 bushels per acre
Ammoniacal copper carbonate	163 bushels per acre
Check row, untreated	162 bushels per acre

The above figures are averages. The gains were somewhat different from the use of bordeaux mixture on White Star potatoes alone: 323 bushels per acre from the sprayed, 251 bushels per acre from the unsprayed.

[1] Vt. Sta. Bul. 44 (1895); Vt. Sta. Rpt. 8, pp. 93-104 (1894).

The addition of the soap was found to be of no avail and the ammoniacal copper carbonate was proved unadapted to this purpose. It was developed, moreover, that old mixtures seemed to lose considerable of their effects on account of aging.

The dry weather favored the attacks of the flea beetle. The average number of holes per leaflet in the unsprayed row were found by counting to be 262, while the sprayed row averages were 12.

1895. The previous years' results had clearly shown bordeaux mixture to be the best potato fungicide. Certain forms of the mixture were found to be more convenient to apply than were others, but there was reason to question whether they were of equal value to the properly prepared fresh mixture. The following forms of these more convenient preparations were used in this year's[1] tests for comparison with the ordinary mixture:

(1) Standard bordeaux mixture (7½ pounds of copper sulphate, 5 pounds of lime, 50 gallons of water).
(2) Test bordeaux mixture (7½ pounds of copper sulphate in 50 gallons of water with enough lime, as shown by the potassium ferrocyanide test, to neutralize the copper sulphate).
(3) Stock bordeaux mixture (prepared early in the season according to standard formula but with only half the required amount of water, diluted to required amount of water just before application).
(4) Bordeaux powder made from standard bordeaux mixture. Applied in three ways: (a) dry and undiluted; (b) dry after dilution with three times as much flour; (c) wet after dilution with four times as much water.
(5) "Fungiroid." A commercial powder applied: (a) dry and undiluted; (b) dry after dilution with three parts of flour.

Each of these fungicides was applied three times: July 25, August 13, August 31. The late blight was serious from the first of September onwards and the tuber rot was widespread. The results obtained, expressed in yields per acre, were as follows:

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[1] Vt. Sta. Bul. 49 (1895); Vt. Sta. Rpt. 9, pp. 93-98 (1895).

Treatment	Large sound tubers	Large rotten tubers
Standard bordeaux mixture	389 bushels	67 bushels
Test bordeaux mixture	349 bushels	78 bushels
Stock bordeaux mixture	322 bushels	112 bushels
Bordeaux powder, dry, undiluted	235 bushels	182 bushels
Fungiroid, dry, undiluted	220 bushels	156 bushels
Check, no fungicide	219 bushels	168 bushels

The stock bordeaux, bordeaux powder, and Fungiroid were practically valueless, and the powdered bordeaux when diluted with flour entirely so.

Studies of the early blight were made this year and it was shown to be due to a fungus, *Alternaria solani*, known previously as *Macrosporium solani*. Inoculation experiments proved that this fungus would produce typical spots of the disease on potato leaves.

1896. Three variations of bordeaux mixture were tried:[1]

(1) Standard bordeaux mixture (7½ pounds copper sulphate, 5 pounds lime, 50 gallons water).
(2) Half-lime bordeaux mixture (7½ pounds copper sulphate, 2½ pounds lime, 50 gallons water).
(3) Bordeaux powder (the precipitate of standard bordeaux mixture dried and ground. Applied with a "powder gun").

Polaris potatoes were sprayed twice, August 7, August 21, with the above mixtures. No late blight or rot occurred. The results indicate that the half-lime bordeaux was as good as the standard but not as safe to use. The bordeaux powder seemed to be valueless.

1897. No extensive comparative trials of fungicides were made.[2] Previous experience had shown the bordeaux mixture to be so superior that a continuation of such trials was deemed to be of but little value. Part of one field was sprayed twice with standard bordeaux mixture and part of another field was sprayed three times: July 27, August 17 and 28. The results stated as bushels per acre were: Sprayed twice with bordeaux mixture,

[1] Vt. Sta. Rpt. 10, pp. 52-53 (1896).

[2] Vt. Sta. Rpt. 11, pp. 190-192 (1897).

124; unsprayed check, 90; sprayed three times with bordeaux mixture, 151; unsprayed check, 80.

1898. Tests were made of three forms of bordeaux mixture:[1]

(1) Standard bordeaux mixture (7½ pounds copper sulphate, 5 pounds lime, 50 gallons water). The copper sulphate was dissolved in 25 gallons of water, and the two poured together.

(2) Improperly made bordeaux mixture. (The concentrated lime water [1 pound to the gallon] was added to the concentrated copper sulphate solution [1 pound to the gallon] and then diluted to 50 gallons).

(3) Commercial bordeaux mixture. (A commercial concentrated mixture called the "Lion Brand" was diluted according to directions and the same quantity used as of the other two mixtures).

The season was a dry one. Great damage was done by tipburn and insect injuries, but little blight occurred. The efficacy of these mixtures as fungicides was therefore not determined. The results were as follows, stated as average yield in bushels per acre:

Fungicide	Dates of application	Marketable tubers	Small tubers
Standard bordeaux mixture,	July 21, Aug. 9, Sept. 9,	239	28
Improperly made bordeaux mixture,	July 21, Aug. 9, Sept. 9,	230	28
Standard bordeaux mixture,	Aug. 9, Sept. 9,	186	20
Commercial bordeaux mixture,	Aug. 9, Sept. 9,	159	34
Check, no fungicide,		112	42

These results indicate that the improperly made bordeaux mixture had nearly as much effect on the plants as had the regularly made mixture. However, it adhered to the foliage less tenaciously and was troublesome on account of clogging the spray nozzle.

The same objections were found with the commercial bordeaux mixture. Furthermore it was found to be expensive, the cost being about 3 cents a gallon, while the home made mixture only cost about 1 cent a gallon.

Two commercial insecticides, bug death and laurel green, were tried but were found to be inferior to the bordeaux mixture containing paris green as preventives of insect injuries.

[1]Vt. Sta. Rpt. 12, pp. 151-156 (1899).

1899. The spraying experiments[1] were tests: (1) Of various insecticides; (2) Of the gain from spraying at different dates.

The standard bordeaux mixture, such as had been used in previous years (7½ pounds copper sulphate, 5 pounds lime, 10 ounces paris green, 50 gallons water) was used as a check on the insecticidal efficiency of paris green mixed with gypsum, and two commercial insecticides, laurel green and bug death. The mixtures were applied July 26, August 17, and September 8. There was little damage done the crop save by insects and tip-burn.

The results are as follows, expressed as yield in bushels per acre:

Nature of application	White Star	Rural New Yorker	Average
Bordeaux-paris green mixture,	227	237	232
Check, paris green in water,	166	168	167
Gypsum-paris green mixture,	179	189	184
Laurel green, 1 pound per acre,	141	197	169
Laurel green, 2 pounds per acre,	151	181	166
Bug death, 3 pounds per acre,	217	190	203
Bug death, 5 pounds per acre,	187	201	194

The efficiency of the bordeaux-paris green mixture was marked. Bug death was shown to have value, but to be prohibitively costly in the amount in which it would have to be applied in field practice entirely to prevent insect injury.

The results from spraying at different dates, expressed as bushels per acre, were:

July 26, August 17, September 8	227 bushels
July 26, August 17	193 bushels
July 26, September 8	203 bushels
July 26	185 bushels
August 17, September 8	150 bushels
August 17	152 bushels
Check, not sprayed	134 bushels

The first application was the most important one, and about one-half the gain was attributable thereto.

[1] Vt. Sta. Rpt. 13, pp. 268-273 (1900).

1900. The tests[1] were made along the same line as those of 1899, viz.:

(1) Of certain commercial insecticides and fungicides. (2) Of the relative values of applications of bordeaux mixture at different dates. Boxal, a commercial insecticide and fungicide combined, and Bodo, a concentrated commercial fungicide designed to take the place of bordeaux mixture, were the commercial mixtures used. Applications were made July 12, August 4 and 23. Neither the early nor the late blights were prevalent, although they were present. The insect damage was serious.

The yields per acre in bushels were: Bordeaux-paris green mixture, 285; control, 224; Bodo, 232. Boxal was not used early enough to compare. The acre yields, when plots were sprayed at different dates, were:

Control, paris green alone	225 bushels
Bordeaux mixture, July 2, July 17	227 bushels
Bordeaux mixture, July 2, July 17, August 4	240 bushels
Bordeaux mixture, July 2, July 17, August 4 and 23	286 bushels
Bordeaux mixture, August 4	234 bushels
Bordeaux mixture, August 4, August 23	285 bushels
Bordeaux mixture, August 23	267 bushels

1901. The experiments[2] were intended to compare dusting the plants with paris green alone with:

(1) Bordeaux-paris green mixture, applied once.
(2) Bordeaux-paris green mixture, applied twice.
(3) Bug death, a commercial powder claiming to be both a fungicide and an insecticide.

Delaware potatoes were planted. Applications of bordeaux and bug death were made on July 20 and August 23, the bug death being used at the rate of 25 pounds and of 62 pounds per acre. Another plot was sprayed with the bordeaux-paris green mixture on July 20 and part of it a second time on August 24. The ravages of blight and rot were severe, affording an admirable opportunity for testing the fungicidal efficiency of the applications.

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[1] Vt. Sta. Rpt. 14, pp. 227-231 (1901).
[2] Vt. Sta. Rpt. 15, pp. 209-215 (1902).

The results stated as yield of potatoes of marketable size in bushels per acre were:

Treatment	Sound	Rotten	Total	Percent rotten
Bug death in water, 25 pounds,	63	131	194	67
Bug death dry, 62 pounds,	66	112	178	63
Bordeaux-paris green mixture,	151	71	252	32
Bordeaux-paris green mixture, July 20, August 24,	170	13.5	183.5	7
Bordeaux-paris green mixture, July 20,	54.3	79.5	133.8	60.

The second spraying prolonged the life of the vines, checked the rot and added 66 bushels to the yield.

1902. Delaware potatoes[1] were sprayed two and three times for comparison with unsprayed plots of the same variety. The standard bordeaux mixture (7½ pounds copper sulphate, 5 pounds lime, 50 gallons water) was used. The late blight and the resulting rot were prevalent and destructive.

The results stated as bushels per acre were:

	Sound	Rotten	Total
Not sprayed,	164	34	198
Sprayed twice,	298	47	345
Sprayed three times,	311	11	322

The infection of the tubers from the late blight resulting in the wet rot is brought about by the spores falling on the ground, working their way through the protecting layer of soil. Hence spraying the soil to kill the spores when they fell on the ground was tried. The branches of the plants on a small area were raised and a spray was directed on August 13 underneath so as to wet the surface of the soil while avoiding the foliage as far as possible; those on a second area were not sprayed in any way; and the tops of those on a third area were sprayed as usual on August 13 and on September 6. The results were as follows in pounds for the three rows used in each treatment:

[1] Vt. Sta. Rpt. 15, pp. 215-219 (1902).

	Sound	Rotten
Soil sprayed,	151	2.5
Not sprayed,	113	26.
Vines sprayed,	182	25.5

There were irregularities in the soil on which the plots were located which made the above results not at all conclusive. Soil spraying is not recommended as a practical remedy; however, it did seem to reduce the rot somewhat.

1903. On one plot,[1] half the rows of Green Mountain potatoes were thoroughly sprayed on August 10 with the standard bordeaux-paris green mixture. The alternating rows were left unsprayed. Late blight did not appear until comparatively late in the season and the one spraying was adequate protection, although blight and rot became abundant.

The yields in bushels per acre were as follows:

	Sound tubers	Rotten tubers	Percent rotten
Sprayed,	361	31	8
Unsprayed,	237	48	17

On another plot, bug death and paris green were added to the bordeaux mixture in order to compare the results when so applied, with those obtained when they were used alone. The loss in the yield was largely due to the late blight of the foliage. The trials of the two years preceding showed that while bug death had value in checking insect ravages it was not effective against the late blight. The following table gives the treatment and the yield from each treatment (three rows) in pounds:

Treatment	Yield (3 rows)
Paris green in water	220 pounds
Control (untreated)	241 pounds
Bordeaux-paris green mixture	278 pounds
Bordeaux-bug death mixture	280 pounds
Bug death, applied dry	237 pounds

[1] Vt. Sta. Rpt. 16, pp. 155-161 (1903); also Bul. 106, pp. 230-232 (1903).

1904. The tests[1] were simply a continuation of the determination of the efficacy of standard bordeaux mixture. Delaware potatoes on two plots and an unknown variety on a third plot were sprayed twice, control rows being left in each case. Late blight did not appear until September, but spread rapidly during that month, owing to the very rainy weather. It caused great loss from rot, one field being hardly worth digging.

The yields stated as bushels per acre were:

	Total yield		*Increase*	*Rotten*		*Net gain*
	Sprayed	Un-sprayed		Sprayed	Un-sprayed	
Field 1, July 26, Aug. 25,	294	234	60	¼	30	90
Field 2, Aug. 5, Sept. 1,	370	368	2	0	48	50
Field 3, Aug. 5, Sept. 5,	344	301	43	27	245	261
Average,	336	301	35	9	108	134

1905. The spraying work was directed along the following lines:[2]

(1) Demonstration of the value of spraying with bordeaux mixture over not spraying at all.

(2) Spraying the soil to prevent the rot.

(3) Spraying as a remedy for early blight.

Bordeaux mixture, consisting of 6 pounds of copper sulphate, 4 pounds of lime and 40 gallons of water with ½ pound of paris green, was applied August 2 and August 21 to Delaware potatoes. The late blight destroyed the tops of the plants that had been left unsprayed as controls, early in September. The results in the bushels per acre were as follows:

	Sound tubers	Rotten tubers
Sprayed,	382 bushels	6 bushels
Unsprayed,	221 bushels	56 bushels

Eight rows of Delaware potatoes planted in heavy, moist clay loam, a soil especially favorable to rot, were used in testing

[1] Vt. Sta. Rpt. 17, pp. 386-391 (1904); also Bul. 111, pp. 27-30 (1904).
[2] Vt. Sta. Rpt. 18, pp. 272-277 (1905); also Bul. 119, pp. 21-26 (1905).

the effect of spraying on the soil. The soil under the plants on four of these rows was carefully sprayed with bordeaux mixture on August 2, August 18 and August 28, care being taken that none of it fell on the foliage. The plants on the other four rows were entirely untreated. As noted above, the blight and rot were bad in September, thus affording ideal conditions for the test. The yield from the four rows was as follows:

	Sound tubers	Rotten tubers	Percent rotten
Four rows, soil sprayed,	60.2	12.5	17
Four rows, untreated,	13.5	57.9	81

While soil spraying was not recommended in practice, it was noted that in the later sprayings when the disease is bad and the soil heavy, it might pay to make extra heavy applications of the mixture in order that enough may reach the surface of the soil to check the development of the fungus spores falling thereon.

Early blight was very abundant on one field and spraying trials were made against it. There were thirty-six rows of potatoes used, each 60 feet long, consisting of six rows each of the following varieties: Rural New Yorker No. 2, Delaware, Green Mountain, Polaris, Early Rose, and Early Ohio. On August 28 the extent of the damage to the foliage on the unsprayed plots was estimated as follows:

DAMAGE FROM EARLY BLIGHT ON UNSPRAYED PLANTS

Variety	Foliage killed	Variety	Foliage killed
Rural New Yorker No. 2,	15 percent	Polaris	50 percent
Delaware,	25 percent	Early Rose	75 percent
Green Mountain,	50 percent	Early Ohio	90 percent

Two rows of each variety were left unsprayed, but were dusted with paris green and lime; two rows were sprayed with the bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 40 gallons water, ½ pound paris green) five times, July 15 and 24, August 2, 18 and 28; two rows were sprayed with the same mixture on July 15, August 2 and August 24.

The following are the yields in bushels per acre:

	Sprayed 5 times	Sprayed 3 times	Not sprayed
Rural New Yorker No. 2,	242	298	222
Delaware,	237	210	93
Green Mountain,	218	198	89
Polaris,	161	169	109
Early Rose,	258	169	48
Early Ohio,	218	230	121
Average,	222	188	114

These results emphasized the beneficial effects of spraying every variety of potato. Five applications are shown to be slightly better than three, but not enough so to make the extra two of much practical consequence.

1906. There were two objects in mind in the 1906 trials:[1]

(1) To continue the demonstration of the practical results of spraying with bordeaux mixture.

(2) To compare the results attained by the use of paris green and lime with those obtained using three commercial compounds: "Copper phosphate," "Dust Bordeaux" and "1-2-3."

(1) A sand loam and a heavy clay loam were used, and Green Mountain potatoes were planted. Bordeaux mixture (5-5-50 formula with ½ pound of paris green added) was applied at the average rate of 130 gallons per acre, twice on the sandy loam, August 13 and August 22, while four applications were made on the clay loam, July 18 and 27, August 8 and 22. The control rows were dusted with paris green and lime (1-20). No late and but very little early blight was present.

The results stated as bushels per acre on the sandy and clay soils were those shown in the table on the top of the next page:

[1] Vt. Sta. Rpt. 19, pp. 265-269 (1906); also Bul. 129, pp. 104-108 (1906).

	Total yield	Marketable tubers	Small tubers
Bordeaux mixture and paris green,	473	411	62
Control, paris green and lime,	371	312	59
Gain from bordeaux mixture,	102	99	3
Bordeaux mixture and paris green,	336	214	117
Control, paris green and lime,	189	128	61
Gain from use of bordeaux mixture,	142	86	56

(2) Four plots were used in this experiment:

(1) Copper phosphate (fungicide only), applied 13 pounds per acre.
(2) Dust bordeaux (fungicide only), applied 17 pounds per acre.
(3) 1-2-3 (fungicide and insecticide), applied 10 pounds per acre.
(4) Paris green and lime.

The copper phosphate, dust bordeaux and 1-2-3 were applied dry over half of the plot while the plants were wet with dew, while on the other half they were mixed with water (1 pound to 5 gallons of water) before application. Paris green (1½ pounds per acre) was added to the copper phosphate and dust bordeaux.

The yields in pounds from the plots were as follows:

	Total yield	Large tubers	Small tubers
Copper phosphate,	198	141	57
Dust bordeaux,	216	151	65
1-2-3,	216	163	53
Paris green and lime,	210	165	45

No late blight was present, so no opportunity was given of testing their fungicidal value. The 1-2-3 seemed to be a reliable insecticide, however, and all the compounds showed the tonic effect on the potato foliage characteristic of the bordeaux mixtures.

1907. The spraying experiments of 1907[1] were designed to show:

[1] Vt. Sta. Rpt. 20, pp. 334-342 (1907); also Bul. 136, pp. 190-195 (1907).

(1) The gain from spraying with bordeaux-paris green and the comparative merits of two, three and of four applications.

(2) The gains from commercial compounds (boxal and bug death) as compared with bordeaux mixture and paris green.

(1) The standard bordeaux mixture (5-5-50) used together with ½ pound paris green. Green Mountain potatoes were sprayed as follows:

Plot I. Bordeaux applied four times, July 16 and 25, Aug. 8 and 22.
Plot II. Bordeaux three times, July 28, Aug. 8 and 22.
Plot III. Bordeaux two times, Aug. 8 and 22.
Plot IV. Control, dusted with paris green in lime.

Early blight was destructive, but no late blight or rot was observed. The results per plot were as follows:

	Large tubers pounds	Small tubers pounds	Total yield pounds	Gain in marketable tubers over check pounds	Gain in marketable tubers over check percent
Plot I. Sprayed four times,	191.9	46.0	237.9	97.1	69
Plot II. Sprayed three times,	144.2	51.9	196.1	41.8	29
Plot III. Sprayed two times,	154.3	51.8	206.1	31.8	22
Plot IV. Check, paris green,	82.6	58.2	140.8		

On September 6 typical plants were examined for early blight and for flea beetle punctures with the following results:

	Leaflets badly eaten by flea beetle	Leaflets badly diseased with early blight
Bordeaux four times, July 16, 25, Aug. 8, 22,	48%	40%
Bordeaux three times, July 25, Aug. 8, 22,	55%	45%
Bordeaux twice, Aug. 8, 22,	95%	75%
Paris green in lime,	97%	80%

(2) Ten rows were used in a comparative trial of boxal, bug death and bordeaux-paris green mixture.

I. Two rows bordeaux mixture (5-5-50, with ½ pound paris green), applied five times, 150-200 gallons to the acre.
II. Two rows, boxal (mixed with water, one pound to 10 gallons), applied five times at the rate of 19 pounds to the acre.

III. Two rows, bug death (mixed with water, one pound to 10 gallons), applied five times at the rate of 25 pounds to the acre.
IV. Four rows, control dusted with paris green mixed with lime, 1 to 20, at the rate of 30 pounds per acre.

On September 6, leaflet counts from the four plots showed the relative damage from the flea beetle and early blight to be as follows:

Treatment	Leaflets badly punctured by flea beetle	Leaflets badly diseased by early blight
Bug death,	52%	47%
Boxal,	60%	60%
Bordeaux,	37%	32%
Paris green and lime,	95%	88%

On September 30, a count was made of the plants still showing living leaves with the following results:

Bug death	17 percent of plants alive
Boxal	4 percent of plants alive
Bordeaux	68 percent of plants alive
Check (paris green)	0 percent of plants alive

The yields from the various plots on October 11 were as follows:

AVERAGE YIELD OF TUBERS OF MARKETABLE SIZE

	Yield of large tubers	Gain over check
Boxal,	144.1 pounds	50.5 pounds or 54 %
Bug death,	127.0 pounds	33.4 pounds or 35.6%
Bordeaux-arsenic,	166.5 pounds	72.9 pounds or 77.9%
Check (paris green),	93.6 pounds	

From the above tables it will be seen that while both bug death and Boxal have insecticidal and fungicidal value, they are less effective than is the freshly prepared bordeaux-arsenical mixture; and they are more costly.

1908. Lime-sulphur mixture was used for comparison with the bordeaux mixture.[1]

[1] Vt. Sta. Bul. 142 (1909).

Bordeaux mixture (5-5-50 formula with one-half pound paris green added) was applied four times to one plot, June 26, July 9, August 5 and 26, and two times to another, August 6 and 26. Lime-sulphur mixture (consisting of 15 pounds of lime in which had been boiled 10 pounds of sulphur, diluted to 50 gallons) was sprayed four times on the same dates as the bordeaux and at the same rate. The control rows were dusted with paris green and lime, 1 to 20.

Two fields were utilized, a sandy loam and a clay loam. But little early blight occurred and no late blight or rot.

Sandy loam, Green Mountain potatoes. Yields in bushels per acre:

Treatment	Large tubers	Small tubers	Total	Gain, percent large tubers
Bordeaux mixture, four times,	145	11	156	154
Bordeaux mixture, two times,	106	11	117	85
Lime-sulphur,	74	13	87	29
Control (paris green),	57	11	68	

Clay loam. Plots 1-3, Irish Cobbler; 4-6, White Star. Yield in bushels per acre:

	Large tubers	Small tubers	Total	Gain, percent large tubers
1 Bordeaux mixture, four times,	76	12	76	128
2 Control (paris green),	37	9	37	...
3 Lime-sulphur, four times,	58	12	58	64
4 Lime-sulphur, four times,	64	16	64	17
5 Control (paris green),	53	12	53	...
6 Bordeaux mixture, two times,	72	11	72	48

While the lime-sulphur mixture was shown to have value by the increase of 37 percent of the sprayed over the control plots, it did not equal the bordeaux mixture in value, for the increase was 67 percent when bordeaux was used twice, and 141 percent when used four times.

1909. As the fungicidal value of bordeaux mixture had been thoroughly demonstrated by the work of the previous years,

the object of the 1909 trials[1] was to determine what constituents of the mixture caused the tonic effect on the potato plant, resulting in an increased yield in years when no diseases except tip-burn were present.

The following applications were made:

(1) Bordeaux mixture (5-5-50 formula).
(2) Bordeaux mixture in which part of the copper sulphate had been replaced by iron sulphate (2 pounds copper sulphate, 4 pounds iron sulphate, 6 pounds lime, 50 gallons water).
(3) Iron sulphate with lime (5 pounds iron sulphate, 5 pounds lime, 50 gallons water).
(4) Bordeaux mixture of the above proportions sprayed on the soil at the same rate as number 1 was applied to the foliage.
(5) Control plots, dusted with paris green and lime (1 to 20).

Paris green at the rate of ½ pound to 50 gallons water was used in the first three cases.

Green Mountain potatoes were sprayed July 12 and 23, August 6 and 26. No late or early blight was present and tip-burn was only fairly abundant.

The yields in bushels per acre from the various plots were as follows:

Treatment	Marketable tubers	Small tubers	Total
Bordeaux mixture,	192	51	243
Bordeaux mixture, plus iron sulphate,	184	51	235
Iron sulphate, plus lime,	117	51	168
Bordeaux mixture on soil,	115	75	190
Control (paris green and lime),	138	50	188

The large increase occurred on the first two plots, i. e., those sprayed with mixtures containing copper. It would seem from this that the copper was the stimulating constituent of the bordeaux mixture.

1910. This work has already been presented in this bulletin, pages 219-225, therefore a rediscussion of it at this point is unnecessary.

[1] Vt. Sta. Bul. 153 (1910).

SUMMARY

The results from the work of the twenty years' spraying may be best seen in the form of a table in which only the yields from the plots sprayed with bordeaux mixture are compared with control plots that have been left unsprayed.

GAINS FROM THE USE OF BORDEAUX MIXTURE ON LATE POTATOES.

Planted	Sprayed	Yield per acre		Gain per acre		Prevalence of late blight
		Sprayed	Not sprayed			
		bu.	bu.	bu.	%	
White Star,						
May —, 1891	Aug. 26, Sept. 8,	313	248	65	26	some
May 20, 1893	Aug. 1, 16, 29,	291	99	192	194	much
May 20, 1893	Aug. 1, 16, 29,	338	114	224	196	much
Apr. 26, 1894	June 16, July 17, Aug. 30,	323	251	72	29	none
May 20, 1895	July 25, Aug. 13, 31,	389	219	170	78	rot
Polaris,						
May 15, 1896	Aug. 7, 21,	325	267	68	26	none
June 1, 1897	July 27, Aug. 17, 28,	151	80	71	89	some
White Star,						
May 10, 1898	July 21, Aug. 10,	238	112	126	112	little
Average, 3 varieties,						
May 18, 1899	July 26, Aug. 17, Sept. 8,	229	161	68	42	little
Delaware,						
May 23, 1900	Aug. 4, 23,	285	225	60	27	rot
May 25, 1901	July 20, Aug. 21,	170	54	116	215	much
May 15, 1902	Aug. 1, 20,	298	164	134	82	severe
Green Mountain,						
May 1, 1903	Aug. 10,	361	237	124	52	severe
Delaware,						
May 25, 1904	Aug. 1, Sept. 1,	327	193	134	69	some
May 15, 1905	Aug. 2, 21,	382	221	161	73	severe
Green Mountain,						
May 27, 1906	Aug. 13, 22,	133	101	32	32	some
May 1, 1907	July 16, 25, Aug. 8, 22,	171	63	108	175	little
May 15, 1908	June 26, July 9, Aug. 6, 26,	156	65	91	140	none
May 28, 1909	July 12, 23, Aug. 6, 27,	243	188	55	29	none
May 9, 1910	July 11, 27, Aug. 15, 23, 30,	240	202	38	18	none
	Average for 20 years,	268	163	105	64	

POTATO DISEASES AND THE WEATHER

Scattered through botanical literature and agricultural journals have appeared numerous references and notes on the effect of local weather conditions on the occurrence and spread of plant diseases in certain regions. Some of these, such as the accounts of the diseases of New Jersey plants, as made by Halsted year after year in the publications of that Station, have discussed the question in detail for the maladies prevalent during each season. He has brought many of these observations together in his interesting paper on "The influence of wet weather upon parasitic fungi." [2]

Many of the stations in this and foreign countries now publish yearly notes on the occurrence and destructiveness of plant diseases. The United States Department of Agriculture through its plant disease survey is also collecting data that should serve as a basis for broad generalizations on the subject.

No attempt has been made, however, so far as the writer is aware, to correlate the relations of the weather and any one plant malady covering a long period of time. The former station botanist (L. R. Jones)[2] studied the relation of the weather to the late blight during the five years, 1891-1895, but has not continued the study during the following fifteen years, further than to make records of striking instances of such correlations. The reason for this apparent omission doubtless lies in the fact that, with the exception of this Vermont data, long time observations on the diseases of a single plant are lacking. It must be remembered that our knowledge of fungi, and especially of their relation to plant diseases, is of comparatively recent origin. However, a fairly complete account of the occurrence and spread of potato diseases has been kept at this Station for the past twenty years and recorded in its publications. Many of these are now out of print. They usually record a single season's observations unrelated to those of other years. It would seem worth while to

[1]Bul. Torr. Bot. Cl. 26, pp. 380-389 (1899).
[2]Vt. Sta. Rpt. 9, pp. 66-71 (1895).

bring them together and to relate them to one another for their own value as well as for the reason cited elsewhere. Furthermore, practically complete local weather records are available covering the same period. These were kept by a cooperating observer, Mr. Walter B. Gates, until the establishment of the United States weather station at this institution. The writer's thanks are due to the present observer at Burlington, Mr. J. K. Hooper, for kindly placing at his disposal the necessary meteorological data.

While the relation between weather conditions and the occurrence of the potato disease is not always clear, there are striking instances of such relationship as will be noted later. The dependence of the spread of the disease upon favorable weather conditions is usually clear. It must be remembered, however, that the potato plant is an exotic of comparatively recent introduction in this country, as well as the fact that it has not as yet become fully acclimated to the weather conditions of Vermont, particularly to its short and comparatively dry summers. Whether the fact that it is a stranger among us has so weakened the plant that it has more easily fallen a prey to fungi or to untoward conditions is not certain, but this much at any rate is clear, that the potato plant has its full share of diseases and that these diseases seem to be largely the result of weather conditions which favor the growth of parasitic organisms.

The principal diseases concerning which the records have been kept at the station are:

(1) Late blight of the potato foliage, produced by the fungus, *Phytophthora infestans*, associated with and following which is the rot of the potato tubers.

(2) Early blight of the foliage, due to the attacks of the fungus, *Alternaria solani*.

(3) Tip-burn, a physiological disease, due to the lack of water, manifesting itself in the scorching of the tips on the leaflets.

The term "potato blight" in popular parlance is applied only to the first of these three maladies, but it has been shown that the other two are also "blights," which under certain conditions are highly destructive. The late blight, however, is the disease upon which the fullest records have been kept, as it is the one which is the most to be feared and which economically is most important. Hence the relations the weather bears to the late blight and rot are more particularly under survey in the following study.

In view of the great destructiveness of the malady and of the fundamental importance of the potato in human feeding, the condition under which late blight first originates and spreads should be of interest wherever it occurs, whether in this country or Europe. In order to make as accurate a picture as possible of these conditions favoring or retarding its growth, a series of charts has been prepared and is shown herewith, displaying for each season not only the curve for both the daily maximum and minimum temperatures for the three months in which blight occurs, July, August and September, but also the daily rainfall and the condition of the sky. The record of the humidity of the air would probably also reveal many interesting relationships but the data thereon is not available. The curves representing daily maximum and minimum temperatures and the black lines for the daily rainfall are all clear on the charts. The condition of the day is represented by the following symbols:

Day entirely cloudy, day partly cloudy, day clear.

Late blight was first recorded[1] in the Vermont station reports as appearing destructively in 1889. It had undoubtedly been abundant before this time, however. Halsted[2] records that in New Jersey "1889 was a remarkable year for the abundance of rain and also for the prevalence of destructive fungi. *Phytoph-*

[1] Vt. Sta. Rpt. 2, p. 121 (1889).
[2] Bul. Torrey Bot. Club, 26, pp. 380-389 (1899).

thora infestans was so abundant in some fields that scarcely a leaf escaped its attacks. Large growers throughout whole sections of the country did not harvest their potatoes, while others dug and placed them in heaps where they rotted."

The late blight and rot were abundant again in 1890[1], being so destructive that active measures—spraying with bordeaux—were taken against it by the then station horticulturist. Halsted reports that potato rots of various sorts were very destructive in New Jersey and that 1890 "has been a year of trouble with potatoes."

On the following odd numbered pages 253 to 291, the Burlington weather data is presented in the form of charts for July, August and September of each year, from 1891 to 1910, while on the even numbered pages opposite to the charts are given the notes on potato diseases derived from the station publications for the year charted on the opposite page, with an attempt to correllate them as nearly as possible with the facts shown on the chart. As noted before, the chart shows four facts regarding the weather for each day:

(1) Upper curve, maximum temperature.

(2) Lower curve, minimum temperature.

(3) Black columns, rainfall; unoccupied area, no rain.

(4) Square at extreme bottom of each chart, amount of sunshine as indicated on opposite page to this note.

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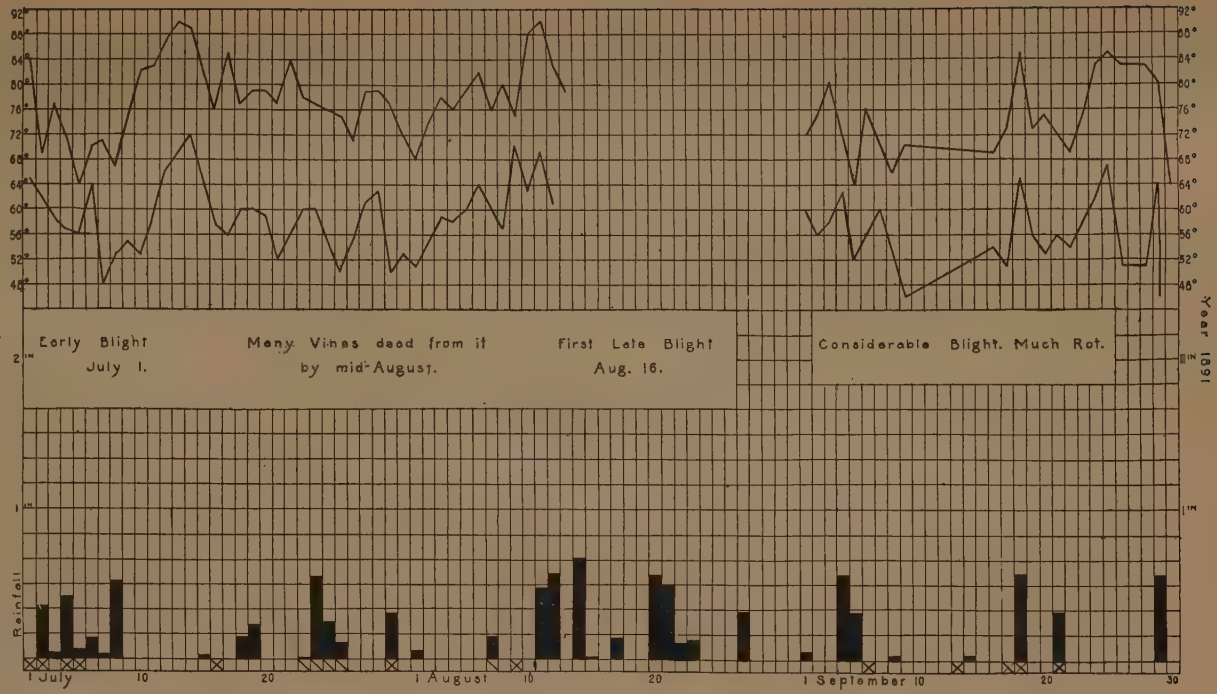
[1]Vt. Sta. Rpt. 9, p. 67 (1895).

1891. The conditions under which blight appeared are discussed by Jones[3] as follows:

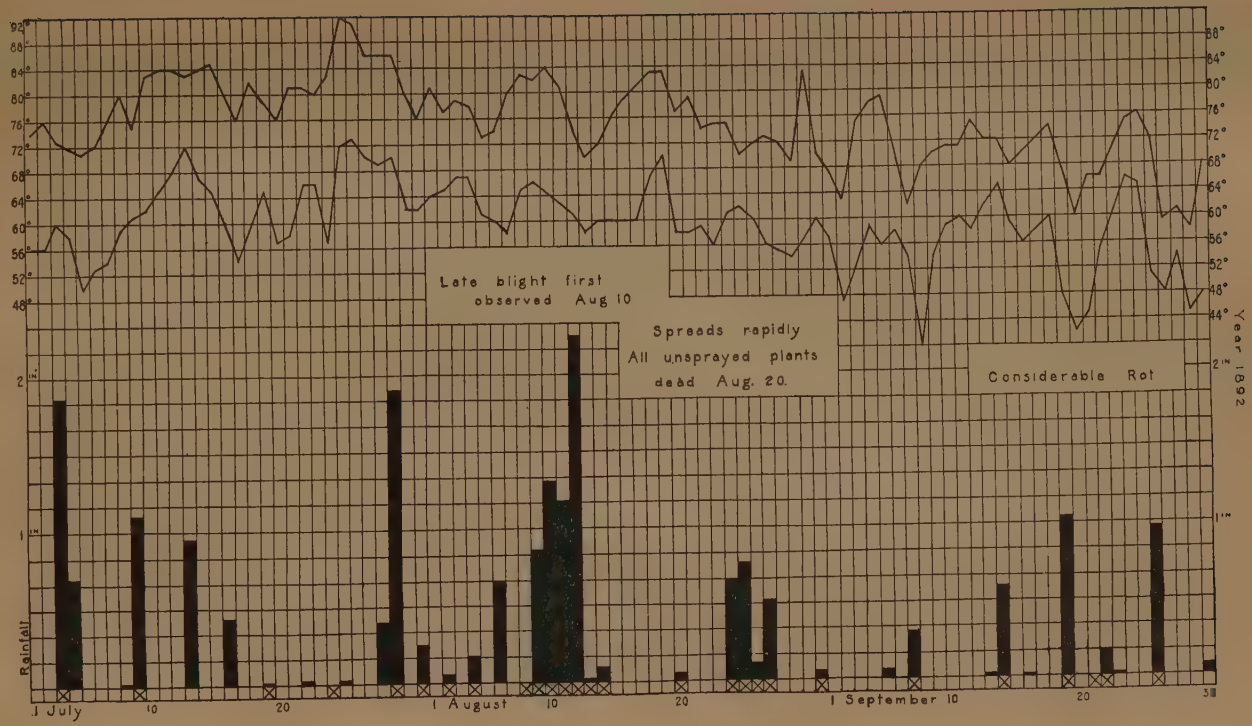
"The temperature was low and rainfall slight. The weather became very warm and on the 12th and 14th was followed by a fall in temperature and copious rains, and this is followed by another rise in temperature and more rains about the 21st. The conditions favoring the blight began thus about the 12th. The blight was first observed the 16th or 17th. When it is remembered that such a fungus requires several days in which to get under way before noticeable injury appears, it is seen that the records place the occurrence of the blight at the time when it might be expected."

The temperature data for this year are not quite complete.

[3] Vt. Sta. Rpt. 9, p. 67 (1895).


92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
48°
Early Blight
July 1.
Many Vines dead from it
by mid-August.
First Late Blight
Aug. 16.
Considerable Blight. Much Rot.
Year 1891
2 IN
1 IN
Rainfall
1 July
10
20
1 August
10
20
1 September 10
20
30

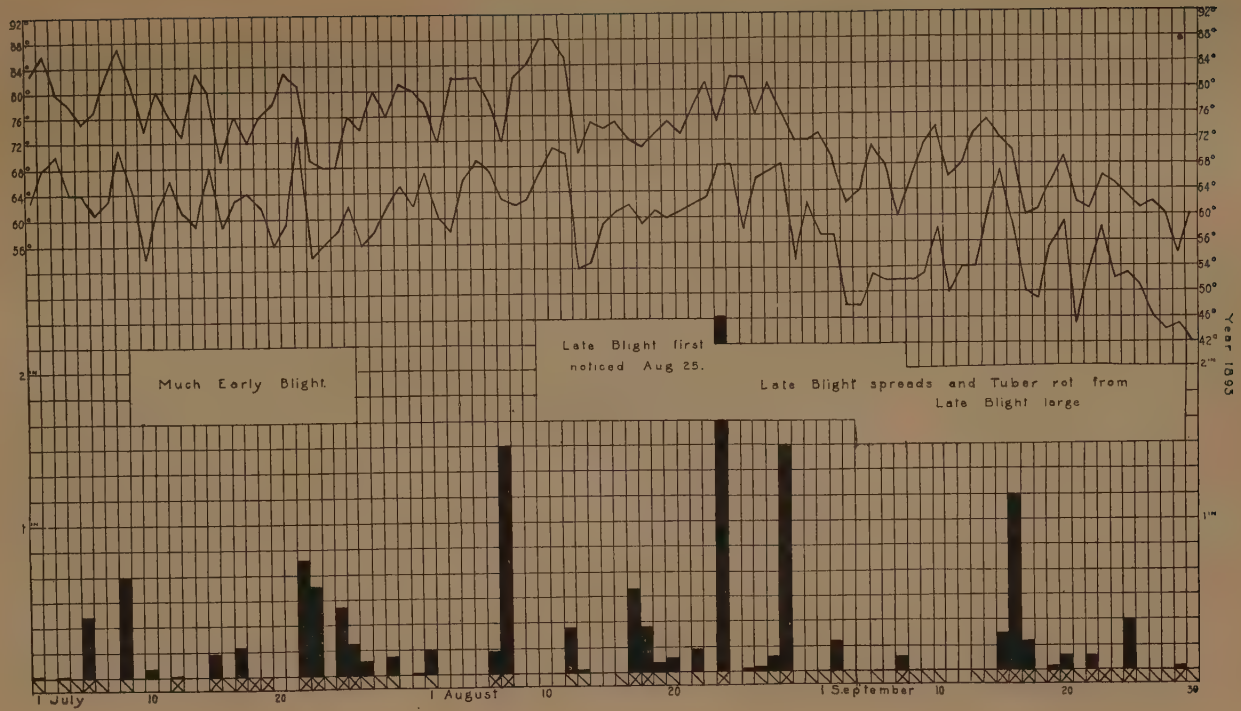
1892. "From August 6th to 12th almost ideal conditions prevail for the blight and reference to the records show that it in reality appeared August 10th, and progressed with unprecedented rapidity so that almost every potato plant was destroyed by it before August 20th."


Late blight first observed Aug 10
Spreads rapidly
All unsprayed plants dead Aug. 20.
Considerable Rot
Rainfall
Year 1892
1 July
10
20
1 August
10
20
1 September
10
20
92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
48°
44°
2 in.
1 in.

1893. "There were conditions favorable for the disease from August 7 to 13, but no blight was observed at that time. However, early potatoes whose tips were dead at the time the blight was first noticed, August 25, showed quite a percentage of rotten tubers; thus it is probable that the blight was present on these early potatoes at the period indicated by the charts as favorable, but escaped observation.

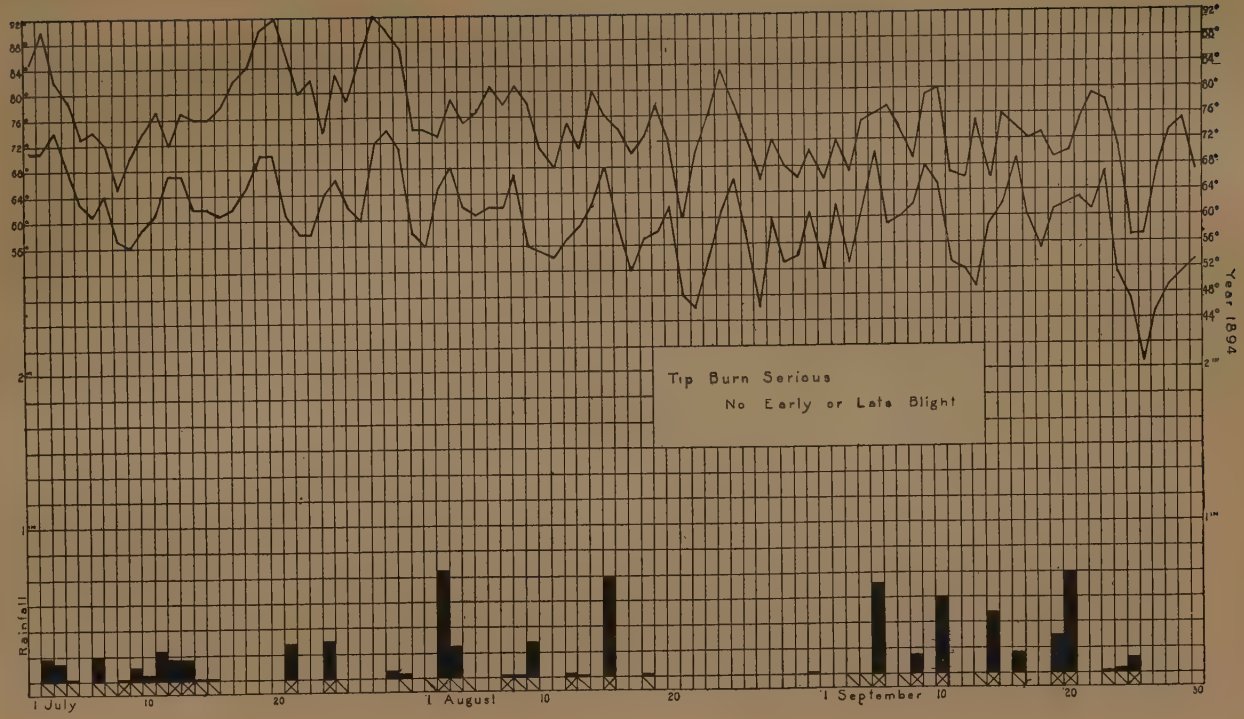
Another bit of evidence pointing this way is the fact that a piece of late potatoes adjacent to these early ones was attacked by the blight fully a week earlier than was another piece in an isolated locality, but planted with the same strain of seed.

The later conditions favoring the blight began about August 22, and the disease is recorded as under full headway by the 25th, and as continuing into September with unusually destructive results."


Much Early Blight.
Late Blight first noticed Aug 25.
Late Blight spreads and Tuber rot from Late Blight large
Year 1893
1 July
10
20
1 August
10
20
1 September
10
20
30

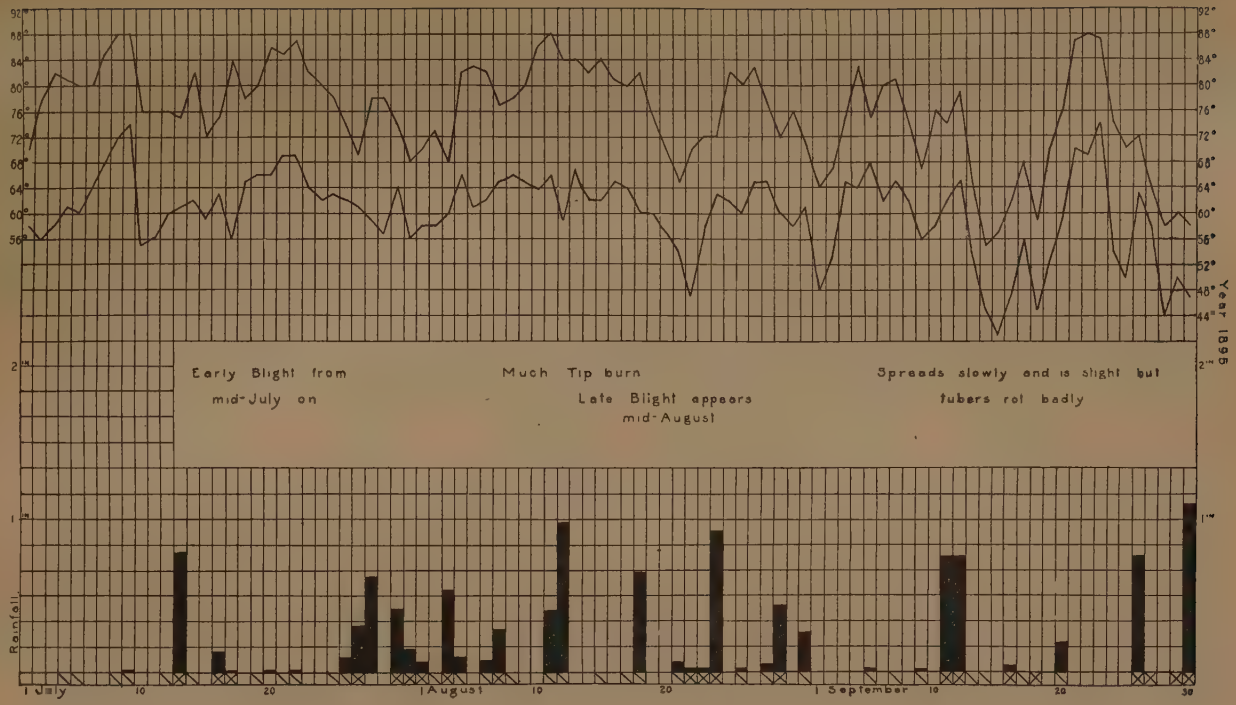
1894. "The weather conditions of this year were very peculiar and prevented the appearance of much blight. July was hot and dry while August was cool and dry. The average maximum temperature for July was 80.1° the minimum 64.4°; the average maximum for August was 73.7° the minimum 58.3°. The rainfall for July was only 1.57 inches and for August 1.49 inches. The drought was the most severe in decades. No late or early blight was observed on the foliage, but a few tubers dry rotted in the bins showing that the disease had been present.

Tip-burn, of course, was prevalent and caused the early death of the potato foliage."


Tip Burn Serious
No Early or Late Blight
Year 1894
Rainfall
92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
48°
44°
2"
1"
1 July
10
20
1 August
10
20
1 September
10
20
30

1895. "The late blight was tardy in developing this year although conditions were favorable for it during early August. The rise of temperature on August 4 continuing until about August 20 may have checked it if any stray infections occurred. The conditions in 1894 were decidedly unfavorable to the disease and very little could have carried over from that year in tubers, although an examination of the tubers from the plots on the Experiment station farm showed a few affected with dry rot. This would tend to lessen the number of centers of primary infection in the summer of 1895 making them few and scattered. In the latter part of August, probably following the drop in temperature, twentieth to twenty-fourth, the disease appeared and from then on spread slowly. The result was much rot to the tubers in the field."

"The tip-burn and early blight were about equally abundant on the experimental plots that had been left unsprayed during August. The early blight appeared in the middle of July and continued to the first of September."


Year 1895
Early Blight from mid-July on
Much Tip burn
Late Blight appears mid-August
Spreads slowly and is slight but tubers rot badly
Rainfall
1 July
10
20
1 August
10
20
1 September
10
20
30

1896. Abundant infected tubers were undoubtedly carried over from the preceding season and the rainfall during July and August ought to have been sufficient to cause the disease to appear. The temperature continued high, however, and this may explain its absence at Burlington. Very little dry rot was found in the potato bins during the winter.

During the hot weather of July and early August the tipburn and blight became prevalent and destructive.[1]

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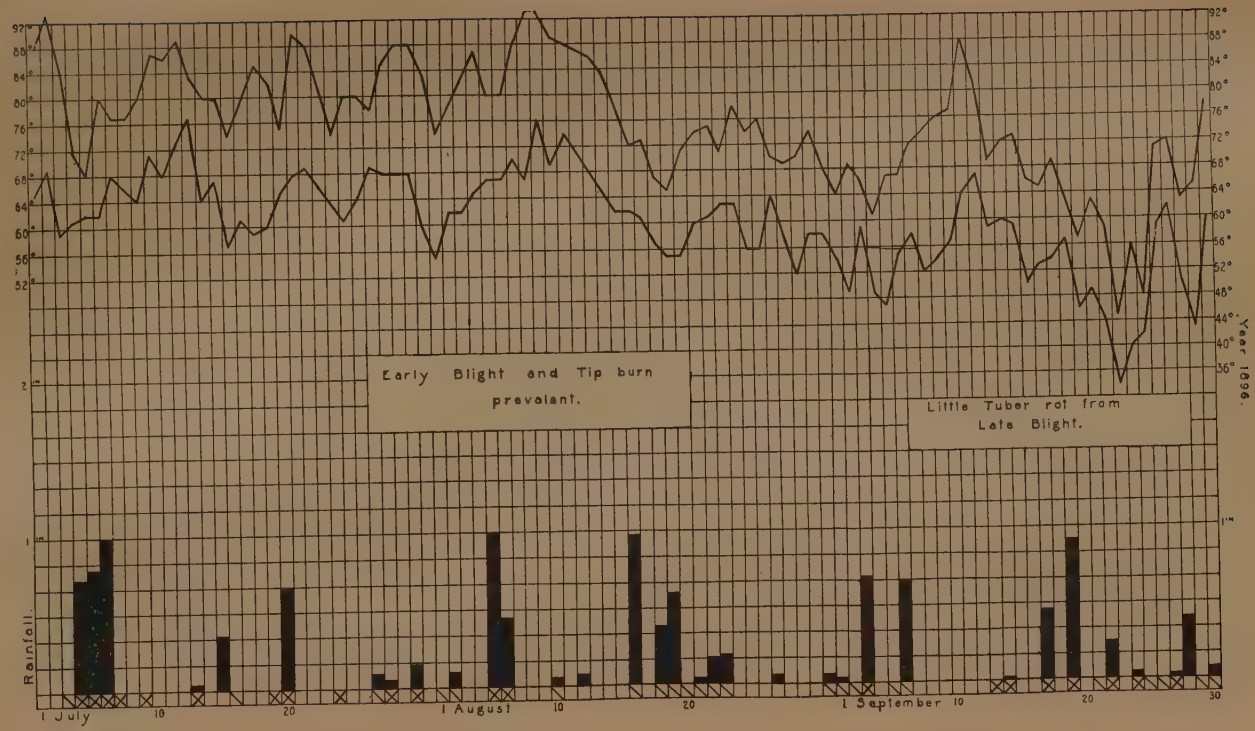
[1] The statements made as to the prevalence of disease for the years 1896 to date are derived from those appearing in the several station reports for the corresponding years as cited in the footnotes on pages 225-246 of this bulletin, to which such persons as are interested are referred.

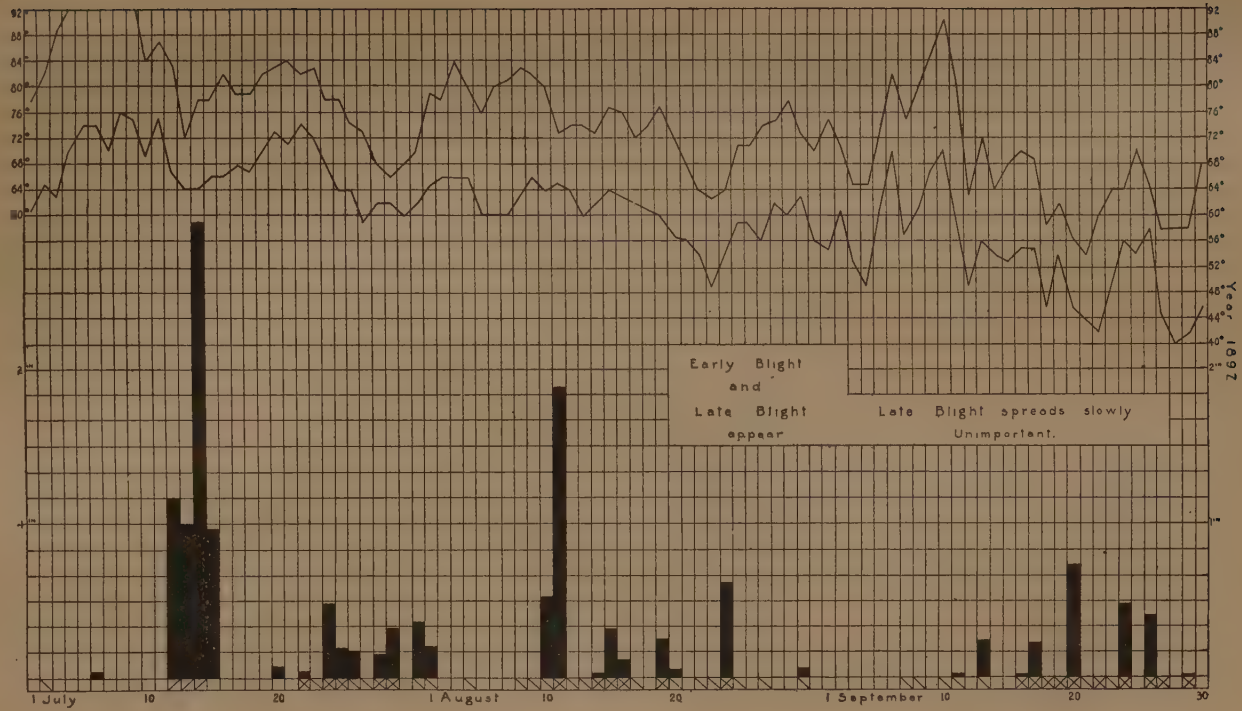

Early Blight and Tip burn prevalent.
Little Tuber rot from Late Blight.
Rainfall.
Year 1896.
1 July
10
20
1 August
10
20
1 September
10
20
30

1897. A heavy amount of rainfall combined with much cloudy weather should have produced a bad attack of the Phytophthora; yet the disease did not appear until late August, when it developed with unusual virulence upon the earlier planted potatoes. The absence of many primary centers of infection from 1896 may, as in 1895, have been a prime factor in its late appearance. Tip-burn was prevalent and had already destroyed most of the foliage by the time the late blight appeared, the plants being so nearly dead before the Phytophthora began its spread that there was a proportionally smaller amount of rot than usual. The following interesting observations were made touching upon this situation.[1]

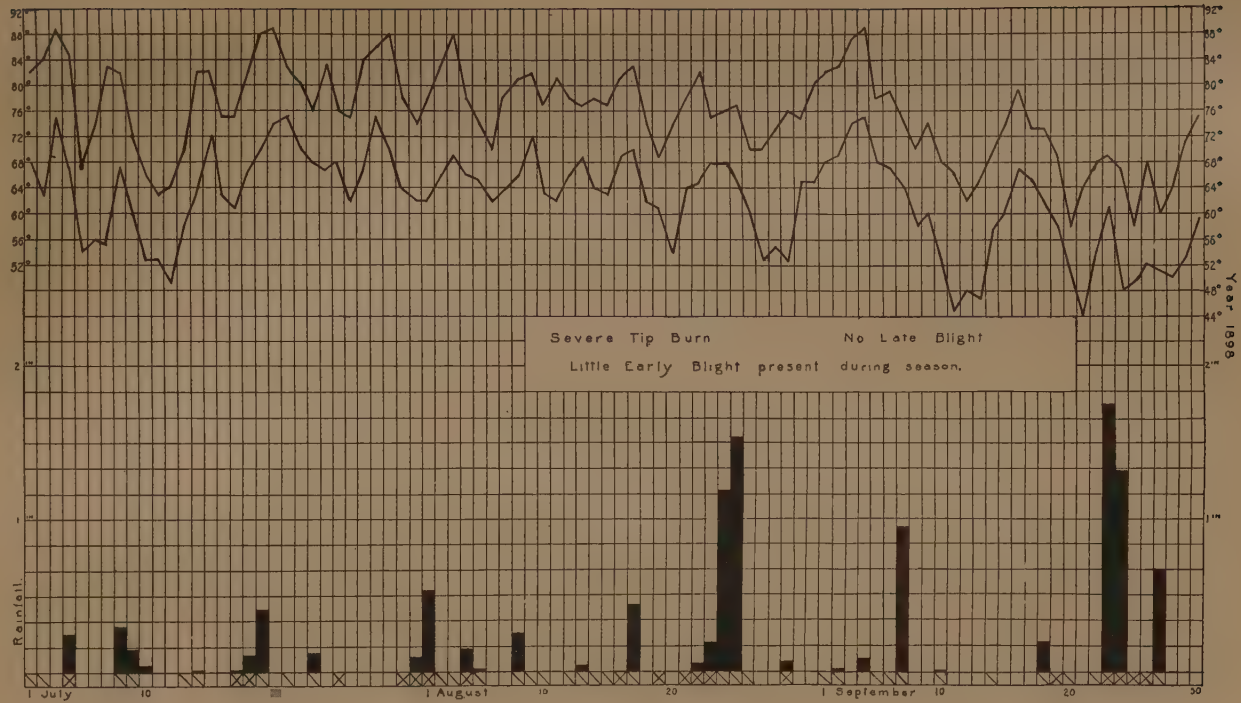
"Owing to the prevalence of cloudy weather the potato plants at the beginning of August were constitutionally weak. Two conditions now operated in combination for their speedy destruction in most of the fields under observation. One was the exhaustive drain made upon the weakly tops consequent upon the formation of tubers; the second was the frequent alternation of exceptionally bright hot days with periods of cloudy or rainy weather. As a result tip-burn developed everywhere, and the greater number of potato plants about Burlington died during August from these causes before the fungus blight developed to any great degree. The relation of this tip-burn to rankness and succulence of growth was clearly shown on certain of our plants on rather poor sandy soil. A portion of these were given a heavy application of commercial fertilizer. The result was a ranker growth and finer looking plants on these fertilized plots up to the first of August. When the trial of resistance came, however, during the next three weeks these suffered considerably more from tip burn than did the unfertilized plants.

It is evident, therefore, that this same form of trouble which we term tip-burn may result from various and quite different unfavorable conditions, especially if these occur at about the time of rapid tuber formation. The conditions of 1897 were peculiar and are not likely soon to be repeated."

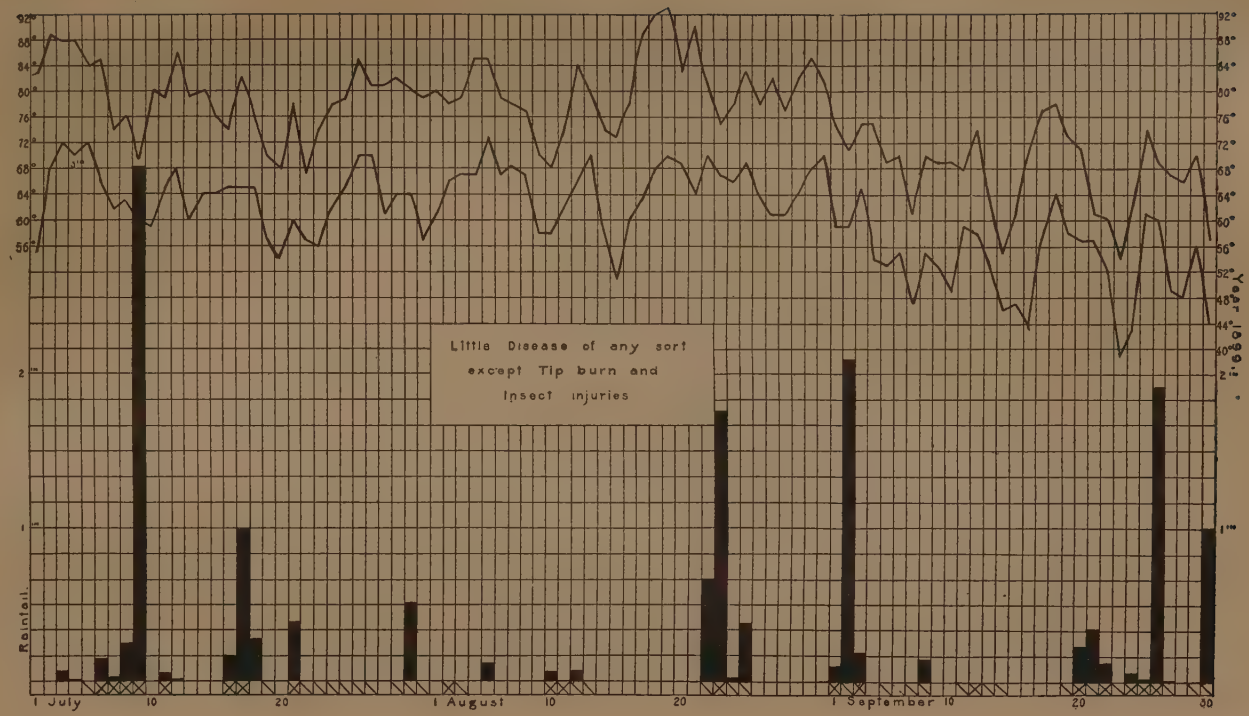
[1] Vt. Sta. Rpt. 11, p. 190 (1898).


Early Blight
and
Late Blight
appear
Late Blight spreads slowly
Unimportant.
Year 1897
1 July
10
20
1 August
10
20
1 September
10
20
30

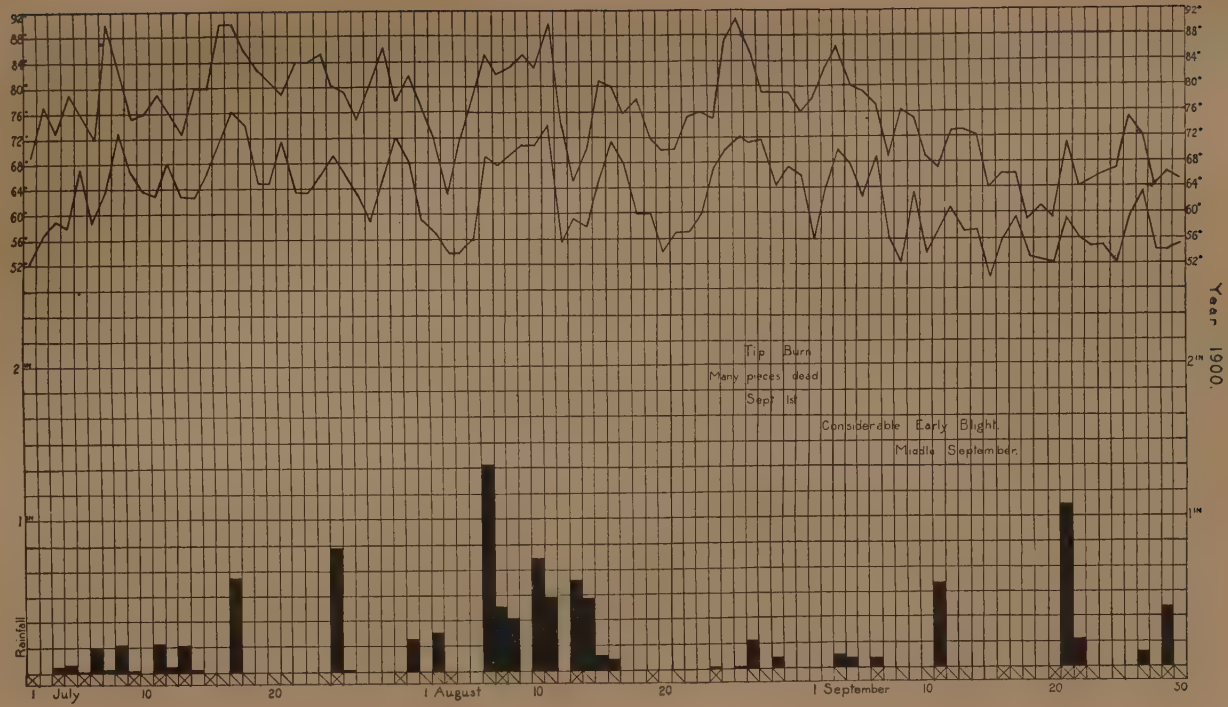
1898. The early and late blights were practically absent from the potato fields around Burlington. While the rains were numerous they were light, and drought resulted during midsummer. The temperature remained consistently high from July 15 to September 5 with the exception of two minor drops of eight to ten degrees in the latter part of August. As a result much tip-burn occurred, practically all the plants on light soil dying during this period, manifesting the characteristic symptoms of tip-burn, while those more favorably situated suffered severely.


Severe Tip Burn
No Late Blight
Little Early Blight present during season.
Rainfall
Year 1898
92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
48°
44°
2"
1"
1 July
10
1 August
10
20
1 September
10
20
30

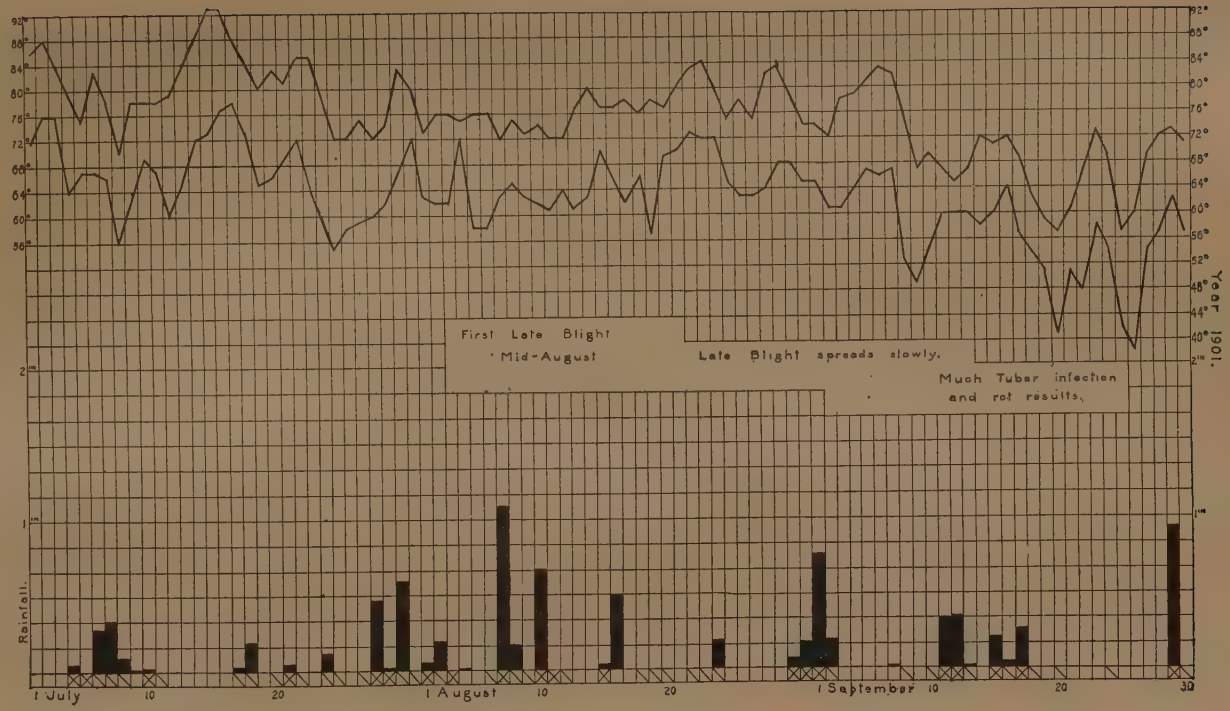
1899. Very little early or late blight was observed around Burlington as the season was very dry from mid-July until the latter part of August, after which time there seems to have been a fair amount of rain. The potatoes on light soils died during this period with all the characteristic symptoms of tip-burn. The yields were greatly reduced from tip-burn and insect injuries.


Little Disease of any sort
except Tip burn and
Insect injuries
Rainfall.
Year 1899.
1 July
10
20
1 August
10
20
1 September
10
20
30

1900. The summer as a whole was a very dry one, the only protracted rainy weather occurring from August 6 to August 16. This was broken, however, by three fair days when there was no rainfall. As a result tip-burn was destructive and many pieces were dead at an earlier date than usual. The reduction of yields was due to this malady rather than to the presence of late or early blight. A little dry rot occurred in some of the fields.

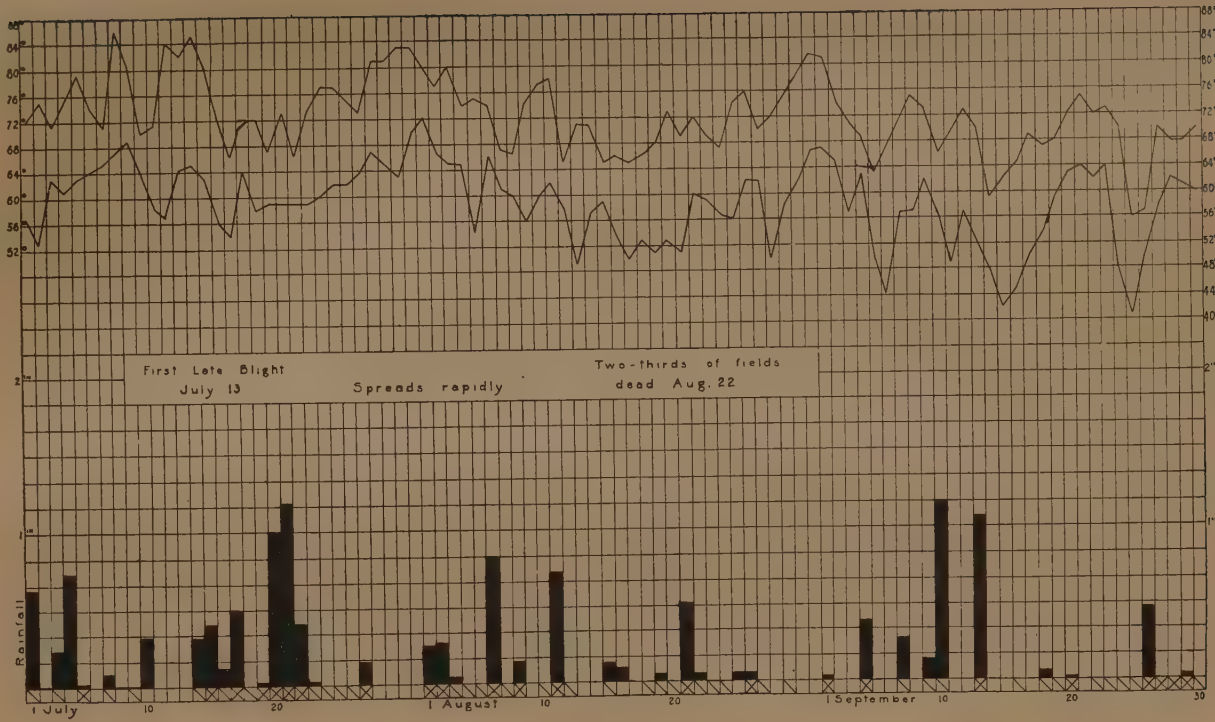

Year 1900.
92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
2 IN
1 IN
Rainfall
Tip Burn
Many pieces dead
Sept 1st
Considerable Early Blight
Middle September
1 July
10
20
1 August
10
20
1 September
10
20
30

1901. The preceding summer had been a somewhat dry one and the summer months of 1901 were still drier; yet this year marked the reappearance of the late blight fungus. The weather following August 15 was not especially favorable to its spread, but there was enough rainfall and cloudy weather to keep it going during the latter part of August and the month of September. A serious rotting of the tubers occurred accompanied by a loss in some cases of from 65 to 90 percent of the tubers. The injuries from tip-burn and from early blight were less than usual, owing to the abundance of water due to frequent small rains and to a lack of high temperature.


Year 1901.
First Late Blight
Mid-August
Late Blight spreads slowly.
Much Tuber infection
and rot results.
Rainfall.
1 July
10
20
1 August
10
20
1 September
10
20
30

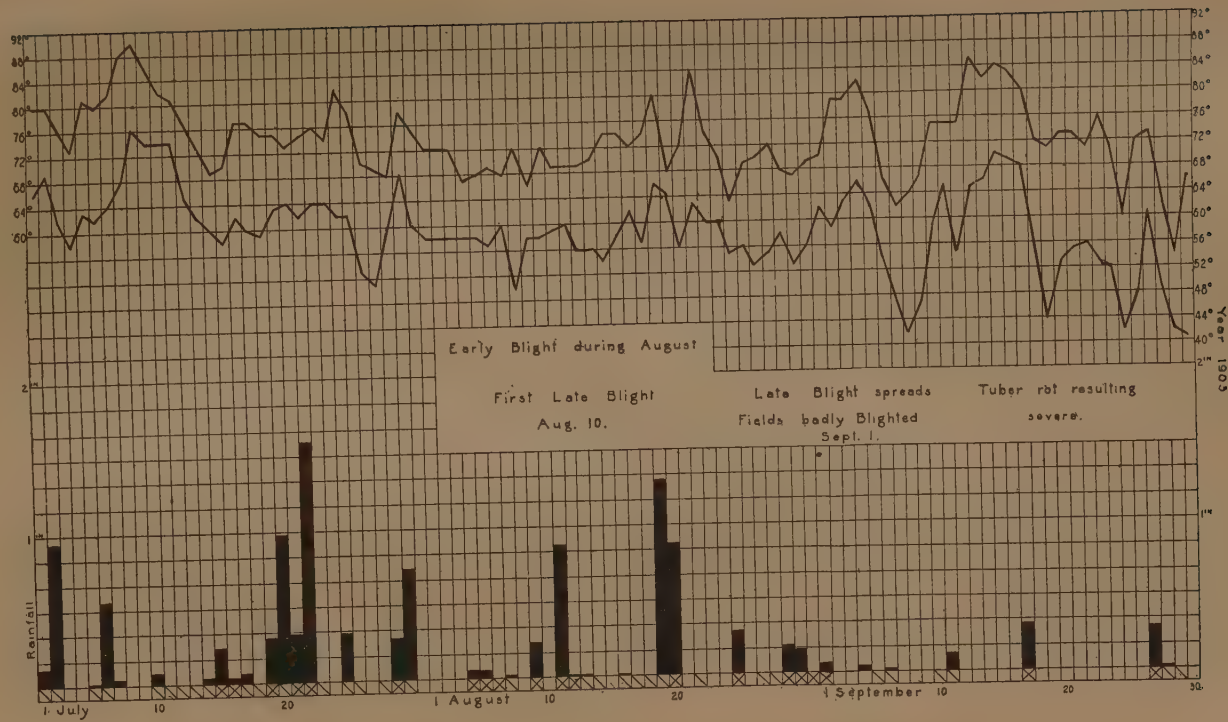
1902. The summer was moist and cool and the Phytophthora appeared at the earliest date on record here, July 13. The abundant infection from the preceding year undoubtedly hastened its appearance. Following this date there ensued a period of wet, cloudy weather, July 14-28, during which time the disease was spreading on the lower leaves of the earlier varieties of potatoes. On the later potatoes planted on higher ground its spread occurred largely during the first two weeks in August, August 1 to 11 being wet and cloudy. During this same period the vines of the early varieties succumbed. A similar period later in the month, August 18-27, finished up the later varieties, so that a canvass of the vicinity of Burlington on August 23rd showed the plants in two-thirds of the fields entirely dead and rapidly dying in the remainder. A large amount of rot of the tubers showed on the moister soils.

The early blight was less prevalent than usual and, the rainfall being abundant, tip-burn did not manifest itself.


First Late Blight
July 13
Spreads rapidly
Two-thirds of fields
dead Aug. 22
Rainfall
Year 1902
1 July
10
20
1 August
10
20
1 September
10
20
30

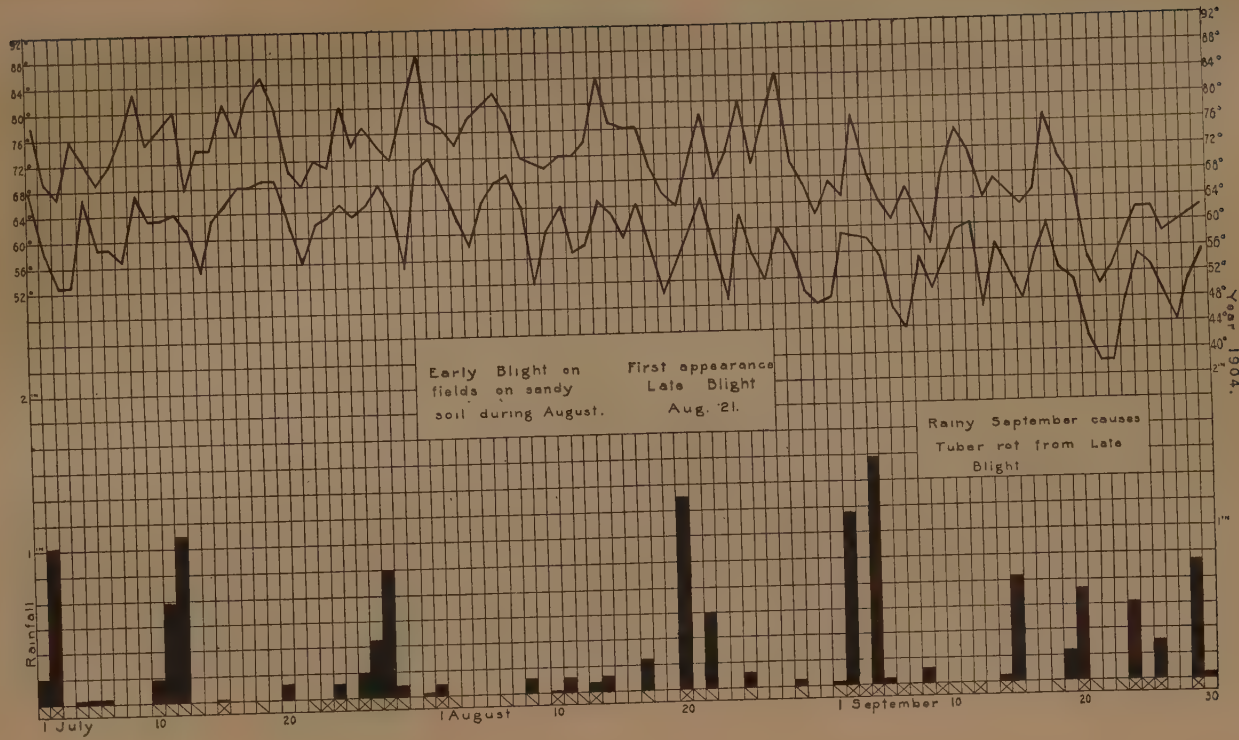
1903. The abundant infection which must have carried over from 1902 did not produce immediate results in the potato fields during this summer, owing to the unusual weather conditions. From the middle of April to the first week in June, there was practically no rainfall. The potato plants did not grow until the rains came at this latter date. By the middle of August, owing to the rains of June and July, there was a fine stand of tops. With the infection of Phytophthora from the preceding year it would seem that a period of damp cloudy weather, such as that occurring from July 10-25, would have caused it to appear; but it was not observed until August 10. It will be noted that while this date was not coincident with a period of heavy rainfall, yet it was coincident with one of low temperature. The relatively cool weather continued throughout August and the disease spread gradually. Practically every field around Burlington, except some pieces on sandy soil, was badly blighted before September first. September was characterized by practically no rainfall and by but few cloudy days, yet the rot from the August infection was general and severe.

The early blight and tip-burn were not serious, although the former appeared during August on the light sandy soils.


Early Blight during August
First Late Blight
Aug. 10.
Late Blight spreads
Fields badly Blighted
Sept. 1.
Tuber rot resulting
severe.
Rainfall
Year 1903
1. July
10
20
1 August
10
20
1 September
10
20
30.

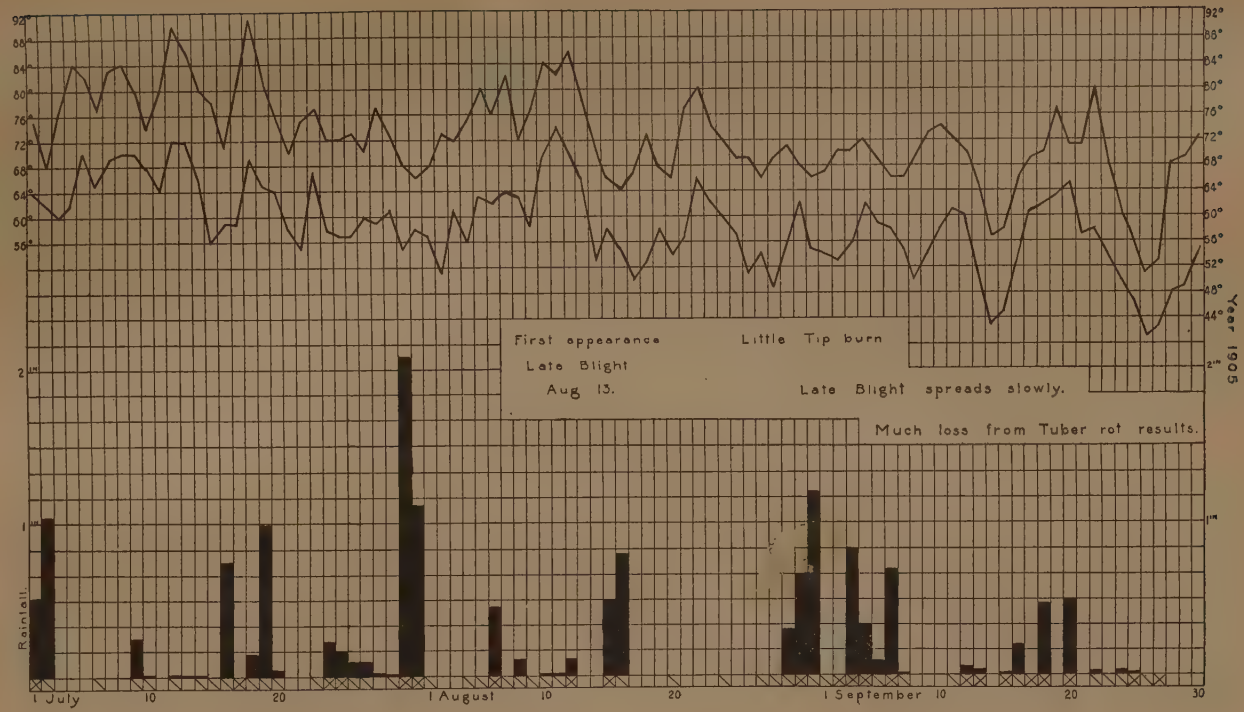
1904. The first late blight was observed on August 21. July and August had been fairly normal as to temperature and rainfall and the infection in 1903 was late in developing. September was rainy with much cloudy weather. The blight spread slowly, not damaging the foliage as much as usual but resulting in much dry rot.

The early blight was destructive in some fields on sandy soil near Burlington.


Year 1904.
Rainfall
Early Blight on fields on sandy soil during August.
First appearance Late Blight Aug. 21.
Rainy September causes Tuber rot from Late Blight
1 July
10
20
1 August
10
20
1 September
10
20
30

1905. Abundant rains during July produced a luxuriant foliage development, and the first late blight was observed on August 13. Heavy rains had occurred on July 30 and 31 and smaller ones on August 6 to 12. Dry weather followed the advent of the disease from August 17 to August 28. This did not particularly favor its spread, but during the first week in September, low temperatures, cloudy weather and almost daily rains caused it to become generally conspicuous. From September 11 to 25 the weather was rainy and cloudy and the conditions were ideal for rot. Many fields on low or heavy soil were not worth digging.

Tip-burn and early blight were comparatively unimportant.


92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
48°
44°
2"
1"
Rainfall.
Year 1905
First appearance
Late Blight
Aug 13.
Little Tip burn
Late Blight spreads slowly.
Much loss from Tuber rot results.
1 July
10
20
1 August
10
20
1 September
10
20
30

1906. Late blight first appeared at Burlington probably between July 20 and August 1. It will be noticed that while there were no heavy rains during July to favor its spread, "the moist warm weather of early July favored the fungus."[1] The infection of the tubers had been so thorough the preceding year that the recurrence of the malady was certain if weather conditions were even moderately favorable. During the latter part of August, and the month of September, however, the weather conditions seemed to check its spread. The reason for this is not entirely clear, but the high temperature and lack of rainfall from August 6 to August 27 may have served to retard it, to dry it up as it were, and the rainfall and low temperatures of September may have served to revive it. Some tuber rot occurred, but there was practically none seen in the main crop.

The early blight was destructive on light sandy soils during late July, and by August 1 it was hard to find a leaf unspotted by this blight in some fields near Burlington. Tip-burn was common after the hot, dry weather of late August.

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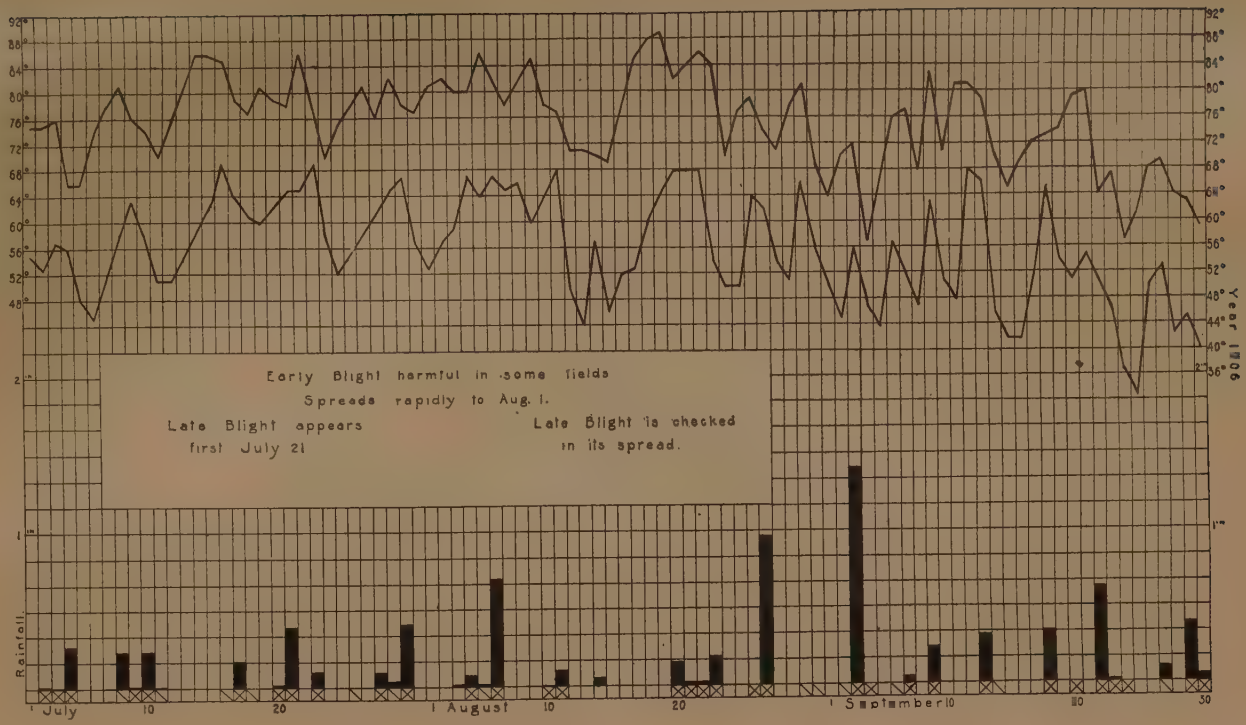
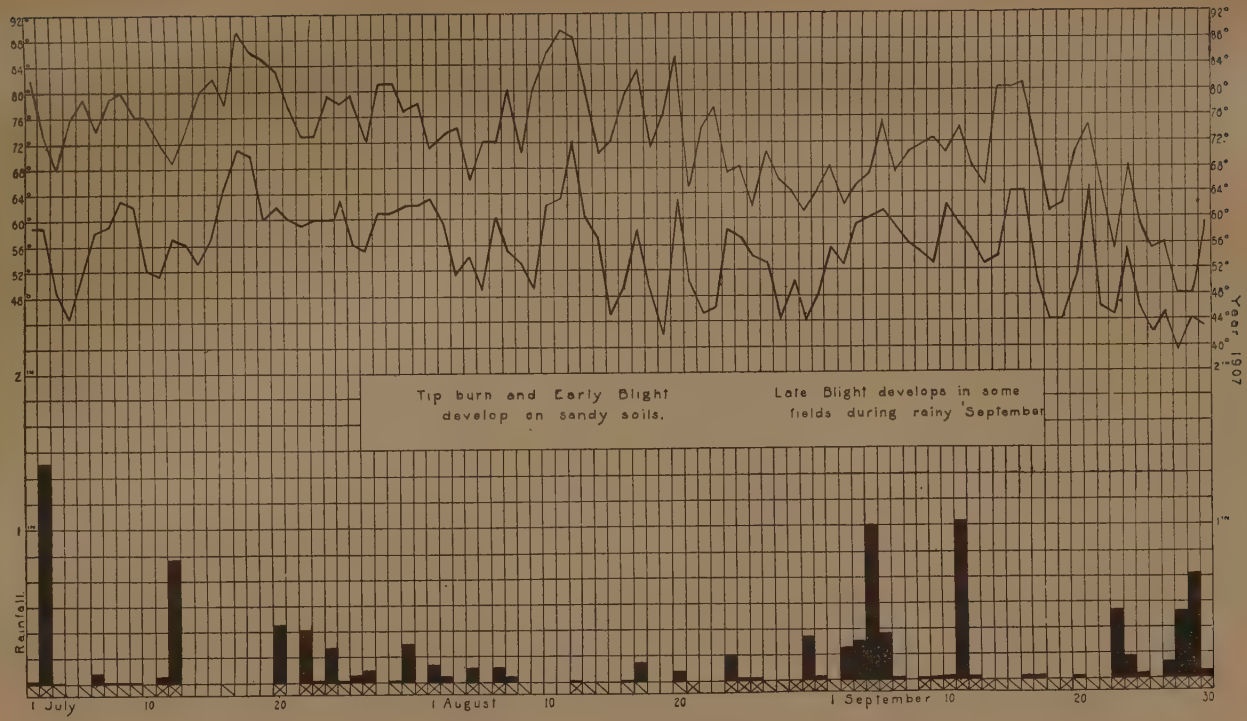
[1]Vt. Sta. Rpt. 19, p. 228 (1906).


Early Blight harmful in some fields
Spreads rapidly to Aug. 1.
Late Blight appears first July 21
Late Blight is checked in its spread.
Rainfall
Year 1906
92°
88°
84°
80°
76°
72°
68°
64°
60°
56°
52°
48°
44°
40°
36°
2"
1"
1 July
10
20
1 August
10
20
1 September
10
20
30

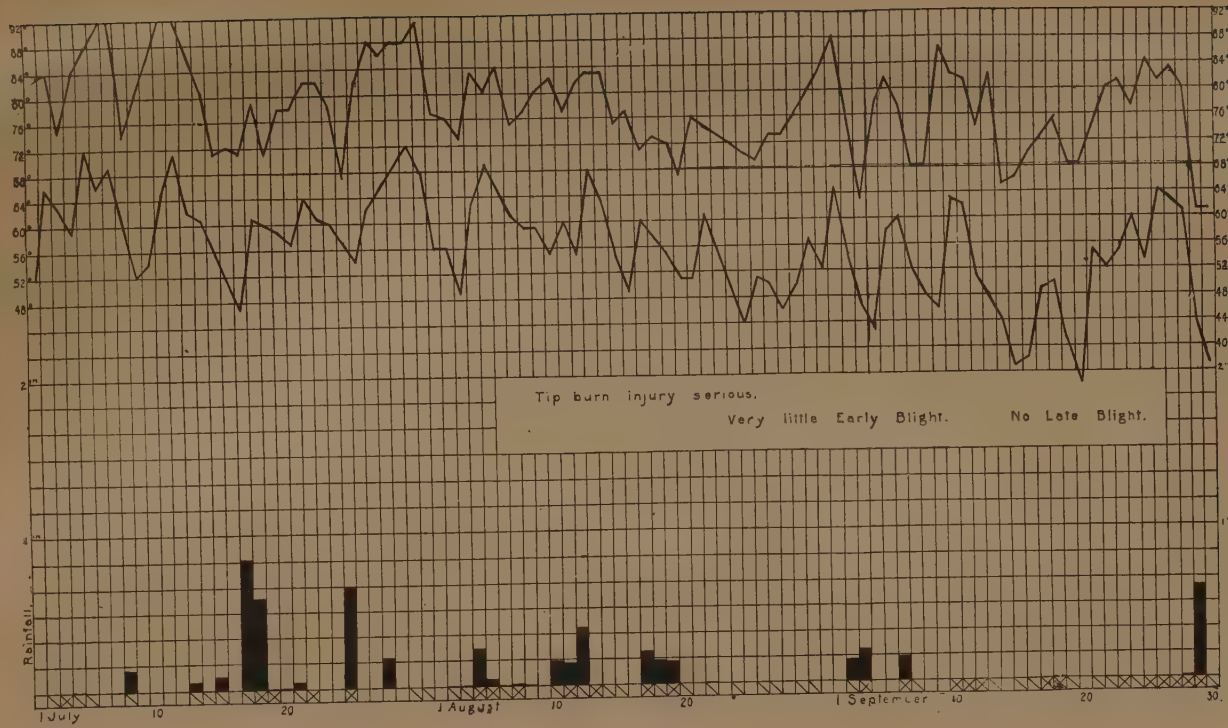
1907. This summer was an average one during July and August as to temperature and rainfall. September, however, had few clear days and rainfall was abundant. As a result the late blight appeared in certain fields around Burlington.

The lack of rainfall during late July and early August caused the development of much tip-burn as well as of early blight on the lighter sandy soils.

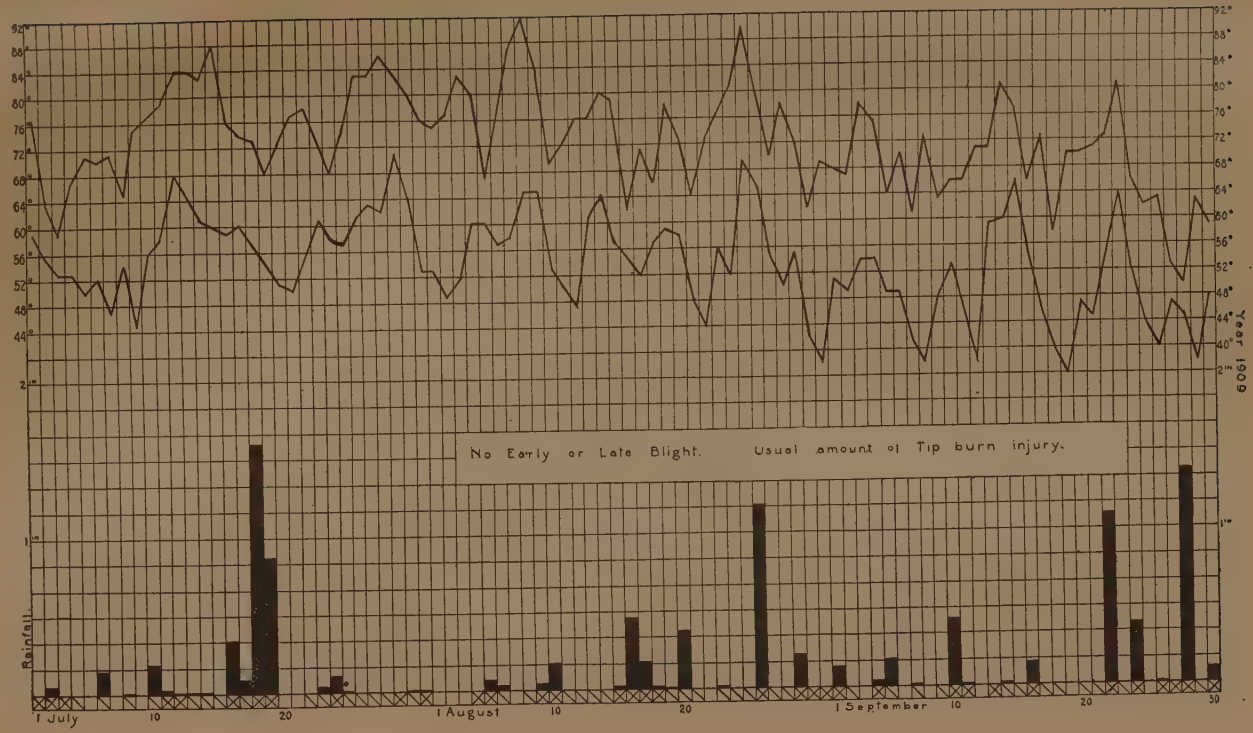

Tip burn and Early Blight develop on sandy soils.
Late Blight develops in some fields during rainy September
Rainfall
Year 1907
1 July
10
20
1 August
10
20
1 September
10
20
30

1908. The late blight was not found this year in the potato fields around Burlington. The very light rainfall was undoubtedly responsible for this. The rainfall of the preceding two years had also been below normal and any tuber infection carried over into 1908 from them must have been small. The dry weather of this year would have prevented the spread from any such diseased tubers.

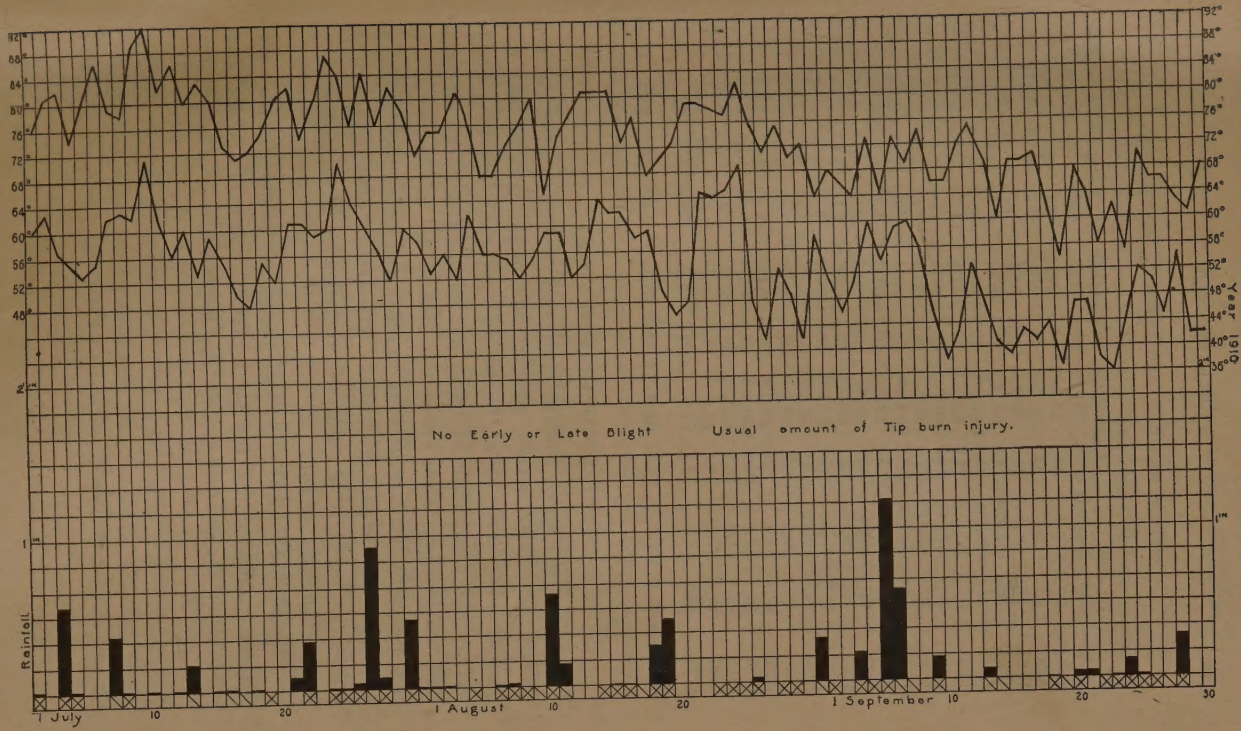
On the other hand, owing to the light rainfall and high temperatures, some early blight appeared and tip-burn injuries were serious.


Tip burn injury serious.
Very little Early Blight. No Late Blight.
Rainfall.
Year 1909
1 July
10
20
1 August
10
20
1 September
10
20
30.

1909. Late blight did not appear this year in the vicinity of Burlington. The preceding year had been such a dry one that no tuber infection was beqeathed by it to 1909. The rainfall, while abundant and about normal, was well distributed and no opportunity for spread of late blight presented itself. There was enough moisture, however, to prevent any early blight and no more than the usual amount of tip-burn injury appeared after the middle of August.


No Early or Late Blight. Usual amount of Tip burn injury.
Rainfall
Year 1909
1 July
10
20
1 August
10
20
1 September
10
20
30

1910. The conditions this year were similar to those of the preceding one and no late or early blight appeared, and only the usual amount of tip-burn injury resulted. The two preceding years had shown no late blight and the rainfall distribution was not such as to spread any chance infection however introduced.


No Early or Late Blight Usual amount of Tip burn injury.
Year 1910
Rainfall
1 July
10
20
1 August
10
20
1 September
10
20
30

AVERAGE MAXIMUM AND MINIMUM TEMPERATURE

Year.	July Max.	July Min.	August Max.	August Min.	September Max.	September Min.	*Rainfall in inches* July	Aug.	Sept.	Total
1891	90.0	51.0	90.3	51.0	85.0	43.0	3.48	3.25	2.44	9.17
1892	92.2	50.5	84.7	54.0	79.0	40.0	7.64	8.36	3.22	19.22
1893	77.5	62.6	77.6	62.8	65.7	51.2	3.74	8.31	2.45	14.50
1894	80.1	64.4	73.7	58.3	71.4	57.1	1.57	1.49	2.88	5.97
1895	79.0	62.1	77.7	61.3	70.8	56.9	2.46	4.84	3.64	10.94
1896	81.7	65.2	77.8	62.5	67.8	53.3	3.83	4.09	3.59	11.51
1897	81.4	67.5	74.7	60.7	68.1	53.6	8.48	4.08	2.13	14.69
1898	78.6	64.4	77.2	63.7	71.2	57.8	1.51	4.58	5.01	11.10
1899	78.8	63.2	80.3	64.9	67.7	53.4	5.30	3.82	6.38	15.50
1900	79.9	65.3	77.6	63.7	70.2	57.3	2.73	5.25	3.20	11.18
1901	80.9	66.8	76.8	64.8	69.8	56.5	2.29	3.18	3.07	8.54
1902	76.7	62.8	73.1	59.7	69.7	56.4	6.23	3.17	3.68	13.08
1903	77.1	63.8	70.8	57.7	72.6	55.6	6.68	4.02	.80	11.50
1904	75.5	62.6	73.9	59.5	64.0	51.7	4.19	2.56	5.84	12.59
1905	77.1	62.9	72.9	59.1	67.3	54.2	7.67	3.98	4.32	15.97
1906	77.4	58.4	78.9	59.0	70.0	50.0	2.33	2.26	3.59	8.18
1907	77.7	58.6	73.4	53.8	66.2	52.8	3.68	1.05	4.76	9.49
1908	82.1	61.2	76.3	55.8	74.8	51.2	2.66	1.65	1.15	5.46
1909	75.5	57.2	75.5	55.0	67.6	48.6	4.06	2.83	4.36	11.25
1910	79.8	58.5	74.7	55.6	66.0	46.9	3.06	2.76	2.75	8.57
Average	79.9	61.4	76.8	59.1	70.2	52.3	4.17	3.77	3.46	11.40

GENERAL CONSIDERATIONS

In the vicinity of Burlington there have been during the past twenty years two severe, general late blight periods and two periods when little or no blight was present. The first blight period was from 1890 to 1894; the second from 1901 to 1906. The two periods when either the disease did not occur or was not abundant were from 1894 to 1900 and from 1906 down to and including the past year 1910. The date of publication of this bulletin is too early to admit of prediction or of statement as to the probabilities of 1911.

Rainfall has much to do with the spread of this disease. The following table shows the total rainfall precipitation for each year during the summer months and the prevalence of late blight:

Rainfall during July, August and September		Prevalence of late blight
1891	9.17 inches	Some blight.
1892	19.22 inches	Much blight and rot.
1893	14.50 inches	Much blight and rot.
1894	5.97 inches	No blight.
1895	10.94 inches	Much tuber rot.
1896	11.51 inches	Very little blight or rot.
1897	14.69 inches	Some blight and rot.
1898	11.10 inches	Little blight or rot.
1899	15.50 inches	Little blight or rot.
1900	11.18 inches	A little dry rot.
1901	8.54 inches	Much blight, 65-90% tubers rotten.
1902	13.08 inches	Severe blight and rot.
1903	11.50 inches	Severe blight and rot.
1904	12.59 inches	Some blight, much dry rot.
1905	15.97 inches	Severe blight and rot.
1906	8.18 inches	Some blight, little rot.
1907	9.49 inches	A little blight.
1908	5.46 inches	No blight.
1909	11.25 inches	No blight.
1910	8.57 inches	No blight.
Average	11.4 inches	

In general it is true that a very rainy season is likely to be accompanied by an epidemic of the disease. This fact is well illustrated by the seasons of 1892, 1893, 1902 and 1905. But there are years like 1897 and 1899 when the rainfall was nearly as heavy and when there was little or no late blight, while on the other hand in seasons like those of 1895, 1901 and 1904 it was hardly above the average, yet the disease was abundant; in fact 1901 was one of the worst seasons on record both as regards damage to foliage and to tubers; yet the rainfall was small. The year 1894 is a well marked example of how the lack of rainfall prevents the spread of late blight and stops the disease, in spite of its great prevalence during the preceding years.

Clearly it is not easy to define the exact weather conditions that call forth an epidemic of *Phytophthora infestans*. Doubtless rainfall is the chief factor, but it is one that is limited in its effects by temperature and sunshine and also, probably, by winds. Given a high temperature and a clear sky the moisture from a heavy rainfall is soon vaporized, whereas when the thermometer ranges low the water from the same rainfall would remain cling-

ing to the plants. Under these latter conditions the parasitic fungus would have a chance to germinate its spores and to penetrate the potato leaf. A vitally essential piece of data, therefore, in the adequate study of these relations is a statement as to the humidity of the atmosphere at the level of the potato plant. Unfortunately this is not at hand. Had it been it would seem that we might explain, if not the appearance of Phytophthora, at least the cause for its spread. However, the rainfall, temperature and character of the day, i. e., whether cloudy or fair, afford an approximate idea of the amount of moisture in the atmosphere and enable one to deduce the probabilities as to humidity with a fair assurance of essential accuracy.

During the 20 years there have been two cases of this malady being stopped after a series of years when its ravages were serious; in 1894, when a very dry season checked it; and in 1906, after five bad blight years, by the very light precipitation of that season, becoming entirely eliminated in 1908.

There has also been only one example of the reappearance of the blight after a period of scarcity. This was in 1901. This season's record is anomalous. The cause of the severity of the rot is hard to explain. The foliage blight does not seem to have been excessive, yet evidently there was enough everywhere present in the field thoroughly to infect nearly every tuber. The rainfall, however, was below the normal and the temperature was not far from the average. There had been but little Phytophthora observed during the five years preceding 1901, although the weather conditions of some of these seasons, such as 1899, had been apparently favorable to its development. Fifty-seven percent of the days during the three summer months of 1901 were cloudy or partly cloudy as compared to 60 percent in 1900 and 54 percent in 1899. In other words, the summer of 1901 seems to have been a fairly normal season so far as rainfall, temperature and cloudiness were concerned; yet the disease reappeared after a partial absence of about five years, the fungus was everywhere present and from 65 to 90 percent of